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CIS

FUTURE OF AERONAUTICS

HEARING

BEFORE THE

SUBCOMMITTEE ON TRANSPORTATION,
AVIATION AND MATERIALS

OF THE

COMMITTEE ON
SCIENCE AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES

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FUTURE OF AERONAUTICS

MONDAY, DECEMBER 5, 1983

House of Representatives,
Committee on Science and Technology,
Subcommittee on Transportation, Aviation and Materials,
Washington, D.C.

The subcommittee met, pursuant to call, at 9:30 a.m., in room 2318, Rayburn House Office Building, Hon. Dan Glickman (chairman of the subcommittee) presiding.

Mr. Glickman. Good morning.

Today this subcommittee will turn its attention to the long-term future of aeronautics, a subject that is tied closely to both our national security and economic well-being.

In 1982, for example, the United States experienced an international trade deficit of $35 billion, an all-time high. Yet, as bad as this was, it would have been $15.6 billion worse had it not been for aerospace export, composed mainly of civil and military aircraft. Employment in the aircraft industry was well over 600,000 in the same year. And total sales amounted to about $32.5 billion.

Thus, by any measure, this industry is an economic winner. It is clearly a key contributor to the national economy, and an absolutely vital element of our defense.

As such, we must be concerned about its future. We must be making the necessary investments in research and technology now to keep us ahead of both our military adversaries and our commercial competitors in the next century.

Unfortunately, recent actions by NASA and others don't measure up to these important goals. We seem to have succumbed to technical stagnation. We have busied ourselves with optimizing the technology of the 1950's rather than boldly exploring new areas. As a result, we are left without truly modern civil aircraft and in this age of acute sensitivity to defense needs without a really modern bomber.

In my view, it is high time to change this mind set. We need to get the aeronautical community moving again. We need to return to the spirit of innovation and risk taking that characterized the post-World War II research airplane program. We need to get things started again so that we don't lose the preeminence that we've enjoyed.

Recently, I called on NASA to take the lead—aggressively—in working with the private sector and the military to:

No. 1, develop a vigorous, but flexible modern-day version of the research airplane program that would bring Government support, civilian and military, together with industry, in a cooperative creative push. The governing philosophy should be a no-holds-barred pursuit of new technologies and applications;

No. 2, to focus on new airframe materials and propulsion systems and incorporate them into new aircraft;

And, No. 3, be bold enough to explore in manned flight the aeronautical region beyond the X-15 envelope.

To assist the subcommittee, and the aeronautical community, in adding substance to this broad outline, we have invited a number of expert witnesses—and I might add each of whom has the right stuff—to discuss needs and opportunities into the 21st century. In doing so, we hope to identify priorities for research that will allow us to move beyond obsolescence to the next generation of faster, higher flying aircraft.

Our first witness today is, in my opinion, one of America's true heroes, who only recently began to receive the recognition he deserves.

For many years, General Yeager worked without fanfare, often risking his life in an effort to expand our understanding of flight. At the time of his many trailblazing achievements, few people out side the aeronautical community were aware of their significance. There was none of the high exposure that the space program has enjoyed. Yet, as a result of the research airplane program, far more people have been affected in their daily lives to date than by anything so far in space. So when we ask where the new frontiers are, there is no one who is better equipped to answer.

And now I'd be glad to call upon my ranking colleague, Congressman Carney of New York.

Mr. Carney. Thank you very much, Mr. Chairman.

You have ably expressed the sentiments of many who are impatient with the apparent—apparent lack of progress in aeronautics. There is a growing sense of frustration that we are not moving ahead faster in aeronautics, and a fear that we'll be overtaken by other nations who seem willing to invest a greater share of their resources in pushing back the frontiers.

I, too, have been critical in the past of the conservatism of the aircraft designers. They have not produced the revolutionary new aircraft that I know many of us would like to see. Indeed, the airplanes flying today fly no higher, no faster, than the airplanes of two decades ago.

Certainly the public enthusiasm for the space program is evidence that many Americans want and are ready for bold new adventures. We are impatient, but we can't let that impatience misguide us. Today, more than ever before, we need a clear vision of the future. We need to know where we are going and how we are going to get there. Higher and faster, certainly, but we have to remember that, even with today's subsonic commercial aircraft, there are still a lot of air travelers who spend more time getting to and from the airport than they spend flying.

While Americans are surely ready for a quiet, comfortable, fuel-efficient SST for the foreseeable future, a quiet comfortable, low-cost V/STOL would be an even greater boon to air travel. Likewise the need for a hypersonic interceptor must be balanced against another—a number of other needs, such as a more maneuverable fighter, greater fuel efficiency, and reduced radar signatures, to name a few.

Lacking the quantity of the Russian defenses, our military has historically relied on superior weapons systems. We cannot afford to lose that edge. The research airplane programs of the 1940's and 1950's came about because there was a consensus at that time that we needed to explore in manned flight a number of theories and emerging technologies.

Each of those aircraft had a clearly defined research objective. The X-1 demonstrated that man could fly faster than sound, and each succeeding research aircraft had a definite purpose. For example, the X-5, with its variable swept wing—swept wings, explored the effects of wing sweep with mach number. Later, the handling qualities of blunt-nose reentry vehicles were explored in the lifting body program. The HL-10 and the M-2 were the forerunners of today's shuttle.

Today, a new consensus seems to be forming. New light-weight materials, coupled with the rapid advances in digital computer technology, have opened up exciting research opportunities. The aircraft designers have many options today that weren't available before. We need to see how these technologies can be integrated to realize their maximum performance benefits, and the best way to do that is through an aggressive, adventurous flight research program.

I can certainly support that view. The X-29 research program is such a program. This aircraft, which is being built by Grumman Aerospace, will demonstrate the use—the use of new composite structure technology to prevent divergence of the forward swept wing, as well as to demonstrate the viability of using modern control theory to make a highly unstable configuration flyable.

I'm sure our witnesses here today can enlighten us on other potential research which will prepare us for the 21st century. But before we hear our first witness, I'd just like to say that, although I'm impatient to see the application of these new technologies, I'm also optimistic.

The time is right for an expanded role for flight research because we have been making progress. And second, if we expect NASA to conduct the kind of long-term, high-risk research that we continue to ask of it at these hearings, it isn't enough for us to provide the resources, we must also resist the temptation to manage these resources. We must allow the researchers to fail if we ask them to take the risks.

Thank you, Mr. Chairman. And I join you in welcoming our distinguished witnesses here today.

Mr. **Glickman**. Thank you. Very good statement, Mr. Carney.

Mr. Harkin.

Mr. **Harkin**. Thank you, Mr. Chairman.

I think both you and Mr. Carney have covered all of the things that need be said about the aeronautical research and development program of NASA and private industry.

I just had one thing—and we always tend to think of it going higher and faster—and it is true what Mr. Carney said, we haven't gone higher or faster since the 1960's. But I think there's another element we ought to keep in mind, and that is, while we're—while we haven't gone in that direction, perhaps we're going in the other direction. We're flying slower, we're flying longer. Some of the research being done by Burt Rutan and the EZ's and things like that that are really extending our knowledge of aeronautical design and—in the realm of slow flight.

I also wanted to point out that it's not only just the aeronautical designs themselves, but also the utilization of fuels. I don't think we've done enough research into the full scope of how we can utilize different fuels for aviation.

And last, I'd just say that we have a whole world out there, a Third World, that's just emerging. A lot of these Third World countries are large in area and scope. They're going to demand more rapid transportation than they now have. And, I think, in many cases, many of their unmet needs will be met through aviation. And that's a whole world out there that we aren't—we aren't even looking at. And so when we think of things like general aviation, we have to be thinking of the kinds of aviation needs that these emerging countries are going to need over the next 20, 30 years.

Thank you, Mr. Chairman.

Mr. GLICKMAN. Thank you.

Before you begin, General Yeager, I would like to pay special reference to one of your colleagues in the early aviation programs of America, Scott Crossfield, who, of course, is a consultant to this subcommittee and shares many of your experiences. And without his effort, both in these hearings and the subject matter generally, I don't think that this committee would be taking the leadership that it is in talking about some of the issues.

So, given that, it's a pleasure to welcome you here today. You may proceed as you deem appropriate.

STATEMENT OF CHARLES E. YEAGER, BRIGADIER GENERAL, USAF, RETIRED

General YEAGER. Thank you very much, Mr. Chairman.

Mr. GLICKMAN. Flip the little button there.

General YEAGER. Is that it?

Mr. GLICKMAN. That's it.

General YEAGER. I need a tech order, Scotty.

It's a pleasure to be here.

I'll go back a little bit. Since I retired from the Air Force in 1975, what I've been doing basically is either consulting with the Air Force, or with industry on certain vehicles. And since, I've retired, I've been flying F-18's, F-16's, F-15's and SR-71's and F-20's. So, basically, you will notice that my experience has been in the military field.

Now, back in the days of 1947, when we began our research flying, opening up new frontiers, I saw a natural evolution of research airplanes on the drawing board. We flew a lot of them, including Scott Crossfield's work in the D-558 phase II and the X-15.

I also was involved in the early 1960's as Commandant of the Aerospace Research Pilot School, which basically got a space-oriented mission since our school was principally involved with the training of not only test pilots, but also astronauts in the space mission.

A lot of vehicles were proposed to be used in those days as training vehicles that had capabilities far beyond what we're flying in today—meaning beyond mach 2 and beyond 100,000 feet, with ramjet propulsion systems primarily.

As you know, in the mid-1960's, all of a natural evolution of research airplanes—a stop was put on systems such as the X-20 Dynasoar and the manned orbital laboratory. In my opinion, that was a natural evolution of the research programs that we were involved in beyond the X-15. Right or wrong, the decision was made. I think it was rather naive myself.

Basically, we haven't done any research in the area beyond the X-15 except going into space and certain limited data on reentry vehicles, such as lifting bodies, as Mr. Carney mentioned. And I think there's a real void there, obviously.

Getting into the arena of current fighters and the knowledge that we have in propulsion systems and—and the materials that these airplanes are made of, in the military role as a fighter pilot, I've seen engines developed from our first really good fighter engines, the J-47's that were then the F-86's, through to the PF-100 engines today.

Now, when we finally got into the area of operating at mach 2 and beyond, we went to very complex engines. The J-79, as I recall, in the F-104, was the first engine that required variable inlet guide veins. Also, we went to variable geometry on intake ducts to operate beyond mach 2 because of swallowing the shock and having compression stalls.

This led up to where we were about 8 years ago in the PF-100 engine that was used in the F-15 and F-16. Probably there's no other engine in the world today that will bleed as much energy out of an ounce of fuel than a PF-100 engine.

But, in my opinion, like variable inlet veins and variable geometry systems on the airplane, we went a little far on the complexities of that engine to where, No. 1 we couldn't maintain it, and any erosion on the airfoil at the compressor blades changed the whole balance of the engine and you ended up with stagnation stalls and compression stalls. If it works right, it's a beautiful engine; if it doesn't, you've got problems.

Now, as of 4 to 5 years ago, I think the pendulum began to swing back to a very simple engine. I think we realized it's not necessary to operate a fighter beyond mach 2. The development of missile systems takes care of any airplane who has the capability of accelerating out beyond mach 2 when he's trying to withdraw from a combat situation. And these missiles have been—although were pretty sad in the beginning—they've been developed to where they have very high reliability today.

Now, the same thing holds true with a lot of the components in the fighters that we have today. In my opinion, I think this pendulum swinging back going to a simpler engine and operating at mach 2 with an advanced missile system actually solves our problems today.

Now, that's the military portion of my knowledge and experience that I've been operating with both in the Air Force and since I've retired from the Air Force.

Personally, I think we made a big mistake many years ago in stopping all research in the areas beyond the X-15, also in the areas of people-carrying or commercial transports. The decision that was made about supersonic transport many years ago, that decision—the reason that they made that decision, in my opinion, was wrong, but it ended up as being the right decision to cancel it because of the increased fuel costs. I think they were lucky.

I think the time is very right today to do research in supersonic transport, because the area is there, the market is there, and the need is there. And I think the technology is available today in the propulsion systems and the materials and the aerodynamics.

And I'll—am open for your questions.

Mr. GLICKMAN. So let me try to paraphrase what you said.

You—do you believe that a new research airplane program would be a useful thing for this country?

General YEAGER. Yes. Basically, I sort of paraphrased all of my ideas with there has to be a need for a vehicle. I think that need exists today for a research vehicle that can answer a lot of questions from mach 7 on out to mach 20 in propulsion systems, materials erosion, structures and aerodynamics.

Mr. GLICKMAN. And the spinoff would be in the civilian sector with respect to fast, highflying airplanes?

General YEAGER. To a certain extent, yes, sir.

Mr. GLICKMAN. And would there be some spinoff in the military sector, too?

General YEAGER. There would be a tremendous amount of spinoff in the military.

The problem that we have in the military today is most of the weapons systems that we developed are countering systems that the Soviets developed. And, basically, we have been able to stay ahead of them, in my opinion, from 1 to 2 years. But in space or the arena of space now, we're in a catchup mode.

In the military, as far as I'm concerned—as far as weapons systems, rather, are concerned—I think we've been able to stay a little ahead of them in technology. As far as missions, that's another subject.

Mr. GLICKMAN. What—let me ask you something. How do you judge our competitiveness with respect to the rest of the world in the technology of producing airplanes?

General YEAGER. I think—there's no doubt in my mind that we have the capability and do develop equipment that's far superior to anything else developed in the world.

Mr. GLICKMAN. And how would you judge our current research efforts as they would relate to that in the future?

General YEAGER. I don't think we're putting enough emphasis on research in the arena of the areas that I mentioned, in propulsion and materials and aerodynamics at high speed.

Mr. GLICKMAN. Mr. Carney.

Mr. CARNEY. Thank you, General. I appreciated your testimony.

As far as the research programs are concerned, years ago, we'd have programs going in more areas than one. It seems to me like today, particularly when we talk about military aircraft, we seem to focus on one type of plane and put all our eggs in one basket and go ahead.

This could be a function of cost, or it could be a function of the private sector's unwillingness to go forward with some of their own R&D.

Could you give me your opinion of that, why we don't have three or four companies going out and looking at various new innovative techniques?

General YEAGER. In my opinion, I think it's a matter of profit motivation. In the old days, back in the late forties, early fifties, the cost of research programs were very minor. The spinoff of those research programs were applied immediately to weapons systems, and those weapon systems—we bought many weapons systems in those days because the prices were relatively low compared to today's cost.

Basically, I think a lot of the aircraft companies are reluctant to get into research programs because of the cost, and it doesn't show up in the profit margin. That's my opinion.

Mr. CARNEY. You know, NASA does an enormous job for us, but I often wonder if they don't hold down some of that competition because everyone looks to them to do much of the frontier-type research in aeronautics. I don't know if that could be a problem or not.

General YEAGER. I personally think the research arena has gotten so large and so expensive that NASA can't afford to cover it all. This is where we get into the private industry supporting the research programs. And as I mentioned before, all of these companies are profit-oriented and there is not a lot of profit in research and development with the way the system is run today. There is profit in production.

Mr. CARNEY. Today the tools are a lot better for testing and evaluating planes; you don't have to go through with building an entire aircraft and then start flight testing it.

Do you find that this change is helpful to new generation aviation, or it might have a negative impact on it?

General YEAGER. Well, basically, the capability is tremendous. Today, you are very correct in saying that the way programs are evaluated or the way research is carried out with high mach wind tunnel data that's available to us, also with computer technology that gets into the design and extrapolation of data, is very helpful. Also, the way materials are being developed is very helpful. So that the research, especially that that involves the flying of hardware, is today, if you pardon my expression, a "piece of cake."

Mr. CARNEY. You have a pretty good aircraft before you have to get in the seat of it, I guess.

General YEAGER. Basically, with simulation, there is no surprises.

Mr. CARNEY. It takes that element out of it, right?

You mentioned planes that will fly in an envelope from mach 7 to mach 20. Are they aircraft that you think would be wanted by the military? Is there a mission to have such a high-speed aircraft?

General YEAGER. In my opinion, as I said before, there has to be a reason to develop a system. Obviously, we use the expression of Mig-25's or SR-71's, they don't do an awful lot of damage flying at 80,000 feet at mach 3. And also, just like orbiting vehicles, or people carriers, there is a limit to the speed at which we can operate because, obviously, you've got to start decelerating at a point if you're going to land, say, from New York to Los Angeles. So this reason that I mention, in my opinion, you've got to let that be the governing factor when you're talking about the development of production systems.

Research—we do have the capability, obviously, of flying winged vehicles beyond mach 7. The shuttle is a good example. It goes into space. But every bit of the data that we get from these vehicles is in a transit condition. Today we don't have the steady state capability of evaluating either scramjets or materials under steady state conditions at mach numbers beyond about three today. I think that would be an area that we could look at. It's an expensive area, but it is an area that research can be done.

Mr. **Carney**. But again, you feel there would be a mission for those——

General **Yeager**. It's a research and development.

Mr. **Carney** [continuing]. Hypersonic——

General **Yeager**. It's a research and development mission, yes, sir.

Mr. **Carney**. At this point you look at it as a purely R&D mission and not one where you could take a plane, let's say, that had the capability of mach 10, and just take that and put it into the Air Force inventory and assign it a mission?

General **Yeager**. Basically, because with our reactionary policy today, we only fight what the Soviets develop. If they develop—if our intelligence shows they are developing weapon systems that operate in that area, then obviously we had better get with it.

Mr. **Carney**. What you're saying, I think, is you're suggesting we're not doing it right. We should be out in the forefront and let the Soviets react to us.

General **Yeager**. I don't make national policy.

Mr. **Carney**. Well, if you did, General, would you say that you would like to see that reversed almost immediately?

General **Yeager**. I would depend upon my advisers to tell me so. [Laughter.]

Mr. **Carney**. Well, in a very limited budget you don't have any advisers; you have to make up your mind, General. Would you like to see that reversed?

General **Yeager**. I'm only looking out for my well-being, too. [Laughter.]

Mr. **Carney**. I take someone who has traveled at great speeds and now I want to take him to the other side of aviation, the general aviation area.

I have been of the opinion that here in the United States we are losing great markets in general aviation, the smaller type of aircraft, privately-owned aircraft, smaller vertical—you know, the V/STOL-type things that we could use from here to New York or whatever. You see more and more of these types of aircraft being presented by commercial aircraft companies, but amazingly none of them are made in the United States.

Would you like to comment on that?

General **Yeager**. Well, I wouldn't go so far to say that none of them are made in the United States. I think we are producing quite a few business-type aircraft. But——

Mr. **Carney**. I correct myself on that. The private business types, yes. But like the types that commuter airlines would make, you know, like the Short 360 or the DeHavilland Dash 7, those types of things. We don't have anything right now that presently can compete with that.

General **Yeager**. I think you're getting into the area, in my opinion, where cost begins to—becomes the governing factor, and the cost to produce an airplane is—I'm not telling you anything—is quite a bit higher in this country than it is in another country. And if the guy is in business to make money, he'll buy the cheapest product, because basically they all do the same thing.

Mr. **Carney**. It's not a case of having the major aircraft industries, the commercial airline industries, looking at the bigger planes and having the same type of thing happen to them as happened to our automobile industry 10 years ago?

General **Yeager**. That's what's happening today, since the technology and the knowhow exists both here in the United States and in foreign countries, or other countries such as England, France and Germany, and Russia. The problem is that that need for that size airplane, at that speed, is pretty cut and dried. It is servicing a market here in the United States. I, as an airline, will buy the cheapest product. We have priced ourselves out of the market.

Mr. **Carney**. Thank you.

Mr. Chairman, that's all the questions I have. Thank you, General.

General **Yeager**. Yes, sir.

Mr. **Glickman**. Thank you, Mr. Carney.

Mr. Harkin.

Mr. **Harkin**. Thank you, Mr. Chairman.

General, just to follow up on this area of beyond mach 3, it seems if you're going to go beyond that, you're going to go higher than 100,000 feet. Are you talking about ramjets?

General **Yeager**. Basically, I think 20 years ago we had the capability of producing vehicles powered by ramjets that would operate at mach 4 at 100,000 to 110,000 feet. But here we get back into the expression is there a need for that type of vehicle in the weapons system arena.

In research, in my opinion it's a waste of money if you're doing research that has no application, to date that yet has no application.

Mr. **Harkin**. It could be for transporting materials, men, things like that? It could be used for transport, too, could it not?

General **Yeager**. If you can get the cost down to pound per mile, yes.

Mr. **Harkin**. Again, in the military sense, though—I mean, sure, you want to get the cost down as much as possible, but if you're trying to meet a military mission of getting materiel and men to some point on Earth, in the shortest possible amount of time——

General **Yeager**. Yes, sir, and also be able to operate on less than a 20,000-foot runway when you get there.

Mr. **Harkin**. That's right. You've got to have that, too.

In all the work that we have done over the last few years in this subcommittee, in looking at the AST, the things that really have forestalled us have been, of course, the economics of it, and the environmental concerns. I have often said that once we get over the economics of it—that is, the fuel cost, the materials cost, the loading it up with passengers, enough passengers, more than the Concorde carries—and I believe the environmental concerns are real, but I believe they could be adequately answered—then there's no reason not to move ahead in it into the next century.

We have done some research in the past on the variable cycle engine. I'm just wondering if you have any knowledge of that. Do you think we have gone far enough in developing that variable cycle engine, or—I guess it's more of a general question.

You said in your testimony that you think the time is ripe now to begin developing the AST. I agree with that. And I also agree with your statement—I think I agree with what you said—about the SST. The time just wasn't right for it, just wasn't. We just didn't have enough knowledge and we hadn't done all of the research necessary before we moved into it. And while I may have disagreed also with the decision not to do it, I probably am glad that we didn't do it at that time, because even as far back as we are now in developing the AST, we would be further back had we put all of our eggs in that one basket of the SST.

I guess I'm just asking you about a general comment on the development of the AST. What do you think are some of the stumbling blocks, how about the engines, the variable cycle engines that it seems like we're going to need, materials developments; do you feel fairly confident that we're going to have an AST in the next century?

General YEAGER. I feel confident that we are—I think there has to be a decision made and a speed picked, and the number of passengers to be carried to capture or recapture the world market in transport sales. I think once that decision is made, our industry has the capability, both in propulsion and materials and aerodynamics to develop an airplane that will fly in that regime and also be that size. I think the time is here to start.

Mr. HARKIN. Well, after reading so much about you and following you for all of my aviation career, which has not been all that long, 20 years, the one thing that always comes through in all of the written material I have read about you and, of course, the movie, is that you don't believe in barriers. One of the things we hear all the time is that perhaps we have bumped into some barriers here in terms of height, fast, that kind of thing, and that, you know, perhaps we have just hit this barrier of highest, fastest, that kind of thing, and these things will never come to pass because they're beyond that barrier.

Do you believe there's a barrier there?

General YEAGER. I don't think so. I think to go back and reemphasize the need, also I think there has to be a consensus of opinion on the subject that I mentioned, and that is the size and the speed. I think the market exists out there.

Also, we have the capability of developing it. It's a matter of doing it.

Mr. HARKIN. I guess just—you know, a lot of our vision has gone to the space program, which is good. I mean, I'm a strong supporter of that. But we tend to look at that and really forget about aeronautics here on Earth. It just seems that we need a new national commitment, I think, to that, to balance the two off.

Certainly, we're not going to go back from our involvement in the space. We're going to go ahead, and that's good. But as I said, there's a lot of countries out there developing, Third World countries. People are still going to be moving around the globe, even in more numbers, and wanting to move faster than they ever have in the past. They aren't going to do it by going into outer space. They're going to have to——

General YEAGER. Right.

Mr. HARKIN [continuing]. Have to do it here.

General YEAGER. I agree with you, and I think the time is ripe to start. Because I think we can get an awful lot of good information and data on the size and speed required to operate in the world, and I still, knowing the propulsion systems that are available today, and also with the materials that have been developed, we can produce the propulsion systems that will operate at that mach number, right on after mach 5 or 6.

Mr. HARKIN. Sure, sure.

Well, General Yeager, thank you very much. It's been an honor having you here.

Mr. GLICKMAN. Let me just ask you a couple of questions.

Mr. Harkin brought up the space issue. You know, one of the things that strikes me as a bulk of the cost in sending the shuttle up is the lifting costs. At some point we made the decision to not pursue the X-15 and thereon, and therefore we made the decision that when we were going to go into space we were going to lift these vehicles into space, as opposed to have them either dropped from an airplane or take off like an airplane.

Just in hindsight, do you think that if we had continued our efforts beyond the X-15, that we would have a different kind of space program today—

General YEAGER. I don't think so, Mr. Chairman. Basically, what we have ended up is a recoverable vehicle. I think the reason that the follow-on X-15, X-20 MOL programs were canceled is because they had application to weapons systems and the decision was made that space would be for peaceful purposes. Right or wrong, it was made. I personally think it was a pretty naive decision.

But I don't think the space program today would be any much different from what it is, other than the use of the data that has been gotten over the last 20 years in space.

Mr. GLICKMAN. But is there any reason why we couldn't send a vehicle up into space using more conventional take-off technology rather than being shut up in a launch vehicle?

General YEAGER. It all boils down to stages and acceleration and speed. I think the way it's being done today is really not a lot more costly than going to a variable stage or launching from large aircraft at mach 2 or winged vehicles that recover the first stage. Basically, we're getting into that now.

Mr. GLICKMAN. Yeah, that's what I was going to say. Some of the research now is kind of going into a hybrid situation, and I am just—perhaps some of the spinoffs of a faster, higher flying research airplane might be to accelerate that progress as well.

General YEAGER. Still the cost would be there.

Mr. GLICKMAN. Mr. Harkin also mentioned the space versus aviation part of NASA. Do you think that the aeronautics part of NASA has gotten the attention that it deserved, or do you think we have over-valued the space part of the NASA equation?

General YEAGER. NASA is a rather large organization. It does research in many areas—propulsion, aerodynamics, space, and deep space observation. I think it's like being, you know, a quarterback versus the linemen. Those people in NASA who have been involved in the low end of the speed regime and research and aerodynamics haven't received the emphasis that space has. I think that's probably been a problem with NASA. There is just not enough glamour in developing a STOL private aircraft as there was in the space shuttle.

Mr. GLICKMAN. Well, we appreciate your being here. I was going to ask you a final question, that is, is it fun being the hottest property since Marilyn Monroe, but I have decided that perhaps you might now want to answer that question. [Laughter.] But we are appreciative of the fact that you're here and also the fact that you have elevated national attention to the subject of flight once again.

General YEAGER. Thank you very much.

Mr. GLICKMAN. And coming from a district where we have a lot of jobs dependent upon the production of airplanes, and from a country that relies on that production and sale of airplanes to keep our economy reasonably in order, I think that the emphasis is a very important one.

General YEAGER. Thank you very much. I think us research types can do a lot of things if we get the money. [Laughter.]

Mr. GLICKMAN. Now, that's why we're going to be talking to Dr. Mark and a few other people after you. Thank you, General.

Our next witness is Dr. George Keyworth—I was looking for you—Director of the Office of Science and Technology Policy [OSTP] in the White House. Dr. Keyworth, I think you're on the same panel with Mr. John Steiner, Jack Steiner, Chairman of the Aeronautical Policy Review Committee.

It is a pleasure to have you here, Dr. Keyworth. We have welcomed you here many times before and have been appreciative of your role in trying to enhance the aeronautical programs in terms of the funding levels. Why don't you go ahead and proceed as you deem appropriate.

I would say to all the witnesses that your statements will be included in the record in their entirety, so you may feel free to summarize if you wish.

STATEMENTS OF GEORGE A. KEYWORTH II, SCIENCE ADVISER TO THE PRESIDENT, AND DIRECTOR, OFFICE OF SCIENCE AND TECHNOLOGY POLICY, EXECUTIVE OFFICE OF THE PRESIDENT; AND JOHN E. STEINER, CHAIRMAN, AERONAUTICAL POLICY REVIEW COMMITTEE

Dr. KEYWORTH. Thank you, Chairman Glickman, and members of the committee. I am pleased to have this opportunity to address the subcommittee on the future of aeronautics.

A little over a year ago the administration issued a new Federal policy for aeronautical research and technology, a policy that I believe will have long-term impact on aeronautics in the United States.

It was the result of a highly pragmatic examination by the administration of the Government's role in aeronautics. That policy established challenging national goals for aeronautics and aeronautical research and technology, goals which recognizes that important parts of U.S. strategic and economic security are linked to the preservation of U.S. preeminence in aeronautics and that Government has a central responsibility for maintaining the vitality of the technology.

For example, we depend heavily on technically superior aircraft weapon systems to counter the numerically superior Soviet threat. Today, about one-third of our defense budget goes for the procurement, maintenance and operation of aeronautical systems. Moreover, aircraft will continue to occupy a major defense role, as we see by their prominence in the President's defense modernization program.

In the commercial sector, we need a healthy and competitive civil aircraft industry and the important industrial technology and production base that sustains it. Not only has this proven to be one of the country's most prominent industries and one with a beneficial balance of trade, but our substantial industrial production capacity stands ready to be used for sudden surges in defense requirements.

Mr. Chairman, in spite of our record of success—or maybe because of it—today we face serious challenges to U.S. preeminence in aeronautics from industrial competitors and military adversaries alike. We have to be concerned about these challenges. We have to take very seriously the need to maintain or, in some cases, even regain our lead in this technology which is so much in the mainstream of our national interest.

The aeronautical R&T policy recognizes that goal and sets out a framework of national roles and responsibilities to do just that. It focuses particularly on how to maintain and improve the effectiveness of the highly successful government, industry, and academic partnership that has evolved over the past 70 years.

As a follow-on to the policy, which was published last year, more recently the Office of Science and Technology Policy formed an Aeronautical Policy Review Committee to insure its implementation and to improve the general coordination of aeronautical activities under its purview. This is a senior-level body whose members represent all of the important private and public sectors of aeronautics.

I asked this committee to review, from a national perspective, the Government's long-range aeronautical research and technology plans, with a particular eye to consistency with the policy, to their overall direction, and to their likelihood of permitting timely exploitation of key opportunities. The committee recently reported to me on its findings, and the committee's chairman, Jack Steiner, is here with me today and will give you some additional insights into their findings.

First, though, I would like to share with you a few significant observations from them and from my own experience as science advisor during the past 2½ years.

By far the most significant finding of the original OSTP study and the committee's review concerned aeronautical research and technology itself. Aeronautics is on the threshold of a renaissance—an era in which numerous opportunities exist for making dramatic leaps in technology. Indeed, all currently operational military and civil aircraft could be technologically superseded by the end of the century, only 16 years away.

During the past year we have taken several steps to translate the new policy into reality. Mr. Chairman, as you well know, the administration has restored NASA aeronautics funding to a level that reflects the importance placed on it by the policy.

Let me mention three important initiatives that were part of that new emphasis. Included are support for advanced composite structures technology, and technology for next-generation rotorcraft. Another is the numerical aerodynamic simulator, which will provide a new capability to analyze three-dimensional flow fields through entire aircraft; today this can only be done through wind tunnel and flight experiments.

In spite of the progress made in the past year, we still have much to do. While the goals and overall direction of our current research and technology programs are generally appropriate and consistent with the technical aspects of the policy announced last year, we can still do more to develop more aggressive and more imaginative national vision to guide aeronautics research and technology for the rest of this century.

Ultimately, we must focus more on truly long-term, high-risk research and technology, areas of potential technological breakthroughs, revolutionary new systems and advanced concepts.

We must also remember that aircraft of all kinds are becoming more complex, so we are going to have to look beyond advances in the traditional aeronautical disciplines alone.

The important payoffs in terms of superior aircraft will come from understanding how technological advances in those individual disciplines, such as aerodynamics, materials and structures, or propulsion or other fields interact with one another.

Our challenge from now on is to understand how to integrate these technologies to achieve large advances in systems capability. In fact, this integration will play an increasingly important, if not dominant role in the development of future military and civil aircraft. I would suggest that we now have to consider this umbrella of systems integration as a true new technical discipline and maybe the most important of all.

As I mentioned at the outset, we have unparalleled expertise and capability in aeronautics, and there is much to do. The current fiscal environment, with its recognized limitations on staff and funding resources, challenges our national resourcefulness and creativity.

In the near term, we must adopt a more adventurous approach, be willing to take some risks on potentially high payoff technologies, and we must continually reexamine our Federal missions and priorities to make sure we allocate resources as wisely as we can. This is one of the greatest management challenges facing us today.

But we can't let our shorter term needs distract us from the need for long-term growth and development in aeronautics. And here we require creative leadership, dialog and commitment from the entire aeronautics community.

Moreover, if we want to increase national effort, then we should also take a hard look at such actions as encouraging greater cooperation with industry in our Federal research programs, IR&D ceilings, removing unreasonable antitrust barriers, and improving tax incentives for private sector R&D and investment for increased productivity.

Based upon the committee's recommendations to me, I've requested that NASA and DOD convene with industry and the university community to develop a visionary outlook for the state of aeronautics in the year 2000. Their task is to assess the optimal research and technology development path, facilities, and resources needed to achieve this vision. I've asked them to identify the most important and highly leveraged areas of technology advancement, those that should be pursued most vigorously, and to point to potential new directions and emphases in our aeronautical research and technology plans.

I expect the results of this long-range assessment, which should be completed within the next 6 months, to be an important element in determining new directions and emphases in U.S. aeronautical research and technology plans.

Mr. Chairman, this completes my formal statement, and I would be pleased at this time to answer any questions that you may have.

[The prepared statement of Dr. Keyworth follows:]

PROPOSED TESTIMONY OF DR. GEORGE A. KEYWORTH, II
SCIENCE ADVISOR TO THE PRESIDENT, AND
DIRECTOR, OFFICE OF SCIENCE AND TECHNOLOGY POLICY
EXECUTIVE OFFICE OF THE PRESIDENT

TO THE SUBCOMMITTEE ON TRANSPORTATION,
AVIATION AND MATERIALS
COMMITTEE ON SCIENCE AND TECHNOLOGY
UNITED STATES HOUSE OF REPRESENTATIVES

DECEMBER 5, 1983

HEARINGS ON THE "FUTURE OF AERONAUTICS"

CHAIRMAN GLICKMAN AND MEMBERS OF THE COMMITTEE:

I'M PLEASED TO HAVE THIS OPPORTUNITY TO ADDRESS THE SUBCOMMITTEE ON THE FUTURE OF AERONAUTICS. A LITTLE OVER A YEAR AGO THE ADMINISTRATION ISSUED A NEW FEDERAL POLICY FOR AERONAUTICAL RESEARCH AND TECHNOLOGY, A POLICY THAT I BELIEVE WILL HAVE LONG-TERM IMPACT ON AERONAUTICS IN THE U.S. IT WAS THE RESULT OF A HIGHLY PRAGMATIC EXAMINATION BY THE ADMINISTRATION OF THE GOVERNMENT'S ROLE IN AERONAUTICS. THAT POLICY ESTABLISHED CHALLENGING NATIONAL GOALS FOR AERONAUTICS AND AERONAUTICAL RESEARCH AND TECHNOLOGY, GOALS WHICH RECOGNIZED THAT IMPORTANT PARTS OF THE UNITED STATES' STRATEGIC AND ECONOMIC SECURITY ARE LINKED TO THE PRESERVATION OF U.S. PREEMINENCE IN AERONAUTICS AND THAT GOVERNMENT HAS A CENTRAL RESPONSIBILITY FOR MAINTAINING THE VITALITY OF THE TECHNOLOGY.

For example, we depend heavily on technically superior aircraft weapon systems to counter the numerically superior Soviet threat. Today, about one-third of our defense budget goes for the procurement, maintenance, and operation of aeronautical systems. Moreover, aircraft will continue to occupy a major defense role, as we see by their prominence in the President's defense modernization program.

In the commercial sector, we need a healthy and competitive civil aircraft industry and the important industrial technology and production base that sustains it. Not only has this proven to be one of the country's most prominent industries and one with a beneficial balance of trade, but our substantial industrial production capacity stands ready to be used for sudden surges in defense requirements.

Mr. Chairman, in spite of our record of success--or maybe because of it--today we face serious challenges to U.S. preeminence in aeronautics from industrial competitors and military adversaries alike. We have to be concerned about these challenges. We have to take very seriously the need to maintain or, in some cases, even regain our lead in this technology which is so much in the mainstream of our national interest.

YET WHILE OUR AERONAUTICS INDUSTRY IS BEING CHALLENGED--AND IN CERTAIN AREAS QUITE SEVERELY CHALLENGED--IT'S HARDLY BEING BEATEN. OUR RESPONSE MUST BE TO DRAW ON OUR IMPRESSIVE STRENGTH--THE SUPERIOR SCIENCE AND TECHNOLOGY BASE THAT RESIDES IN INDUSTRY, IN OUR UNIVERSITIES, AND IN FEDERAL RESEARCH INSTITUTIONS. WE HAVE TO FUEL OUR COMPETITIVE SPIRIT AND CHARGE AHEAD, SINCE THE BEST AND SUREST WAY TO WIN THE RACE IS TO RUN FASTER.

WE SIMPLY CAN'T ALLOW OURSELVES--NOR WILL WE ACCEPT--ANY OPTION IN AERONAUTICS OTHER THAN PREEMINENCE. AERONAUTICS' IMMENSE STRATEGIC POTENTIAL, PARTICULARLY FOR DEFENSE, DICTATES A VIGOROUS RESEARCH AND TECHNOLOGY BASE AND DEMANDS A CONTINUED AND STRONG GOVERNMENT INVOLVEMENT TO ENSURE THAT ADEQUATE NATIONAL INVESTMENTS ARE MADE IN RESEARCH AND TECHNOLOGY.

THE AERONAUTICAL R&T POLICY RECOGNIZES THAT GOAL AND SETS OUT A FRAMEWORK OF NATIONAL ROLES AND RESPONSIBILITIES TO DO THAT. IT FOCUSES PARTICULARLY ON HOW TO MAINTAIN AND IMPROVE THE EFFECTIVENESS OF THE HIGHLY SUCCESSFUL GOVERNMENT, INDUSTRY, AND ACADEMIC PARTNERSHIP THAT HAS EVOLVED OVER THE PAST 70 YEARS.

AS A FOLLOW-ON TO THE POLICY, WHICH WAS PUBLISHED

LAST YEAR, MORE RECENTLY THE OFFICE OF SCIENCE AND TECHNOLOGY POLICY FORMED AN AERONAUTICAL POLICY REVIEW COMMITTEE TO ENSURE ITS IMPLEMENTATION AND TO IMPROVE THE GENERAL COORDINATION OF AERONAUTICAL ACTIVITIES UNDER ITS PURVIEW. THIS IS A SENIOR-LEVEL BODY WHOSE MEMBERS REPRESENT ALL OF THE IMPORTANT PRIVATE AND PUBLIC SECTORS OF AERONAUTICS.

I ASKED THIS COMMITTEE TO REVIEW--FROM A NATIONAL PERSPECTIVE--THE GOVERNMENT'S LONG-RANGE AERONAUTICAL RESEARCH AND TECHNOLOGY PLANS, WITH A PARTICULAR EYE TO CONSISTENCY WITH THE POLICY, TO THEIR OVERALL DIRECTION, AND TO THEIR LIKELIHOOD OF PERMITTING TIMELY EXPLOITATION OF KEY OPPORTUNITIES. THE COMMITTEE RECENTLY REPORTED TO ME ON ITS FINDINGS, AND THE COMMITTEE'S CHAIRMAN, JACK STEINER, IS HERE WITH ME TODAY AND WILL GIVE YOU SOME ADDITIONAL INSIGHTS INTO THE FINDINGS.

FIRST, THOUGH, I'D LIKE TO SHARE WITH YOU A FEW SIGNIFICANT OBSERVATIONS FROM THEM AND FROM MY OWN EXPERIENCE AS SCIENCE ADVISOR DURING THE PAST TWO AND A HALF YEARS.

BY FAR THE MOST SIGNIFICANT FINDING OF THE ORIGINAL OSTP STUDY AND THE COMMITTEE'S REVIEW CONCERNED AERONAUTICAL RESEARCH AND TECHNOLOGY ITSELF. AERONAUTICS IS ON THE

THRESHOLD OF A RENAISSANCE--AN ERA IN WHICH NUMEROUS OPPORTUNITIES EXIST FOR MAKING DRAMATIC LEAPS IN TECHNOLOGY. INDEED, ALL CURRENTLY OPERATIONAL MILITARY AND CIVIL AIRCRAFT COULD BE TECHNOLOGICALLY SUPERSEDED BY THE END OF THE CENTURY, ONLY 16 YEARS AWAY.

JACK STEINER AND OTHERS HERE TODAY WILL BE COVERING, IN SOME DETAIL, THE KEY EMERGING TECHNOLOGIES. MANY OF THESE COULD LEAD TO THE DESIGN OF ENTIRELY NEW AIRCRAFT WITH SUPERIOR PERFORMANCE, LOWER OPERATING COSTS, AND GREATER EFFICIENCY. THE TECHNOLOGIES WILL EMERGE FROM SUCH AREAS AS ADVANCED MATERIALS AND STRUCTURES, PROPULSION, CONTROLS, AND ADVANCED CONCEPTS AND CONFIGURATIONS. IN ADDITION, THE MICROELECTRONICS REVOLUTION IS BRINGING RESEARCHERS AND DESIGNERS POWERFUL NEW TOOLS SUCH AS SOPHISTICATED SIMULATORS AND FULL 3-D VISCOUS NUMERICAL SIMULATION. THE RESULT OF THIS STARTLINGLY NEW DESIGN FLEXIBILITY AND CREATIVITY WILL BE REDUCTIONS IN THE TIME, RISK, AND COST OF DEVELOPING FUTURE AIRCRAFT AND SUBSYSTEMS. THESE ARE THE OPPORTUNITIES WE MUST CAPITALIZE ON TO ENSURE U.S. PREEMINENCE INTO THE NEXT CENTURY.

DURING THE PAST YEAR WE'VE TAKEN SEVERAL STEPS TO TRANSLATE THE NEW POLICY INTO REALITY. MR. CHAIRMAN, AS YOU WELL KNOW, THE ADMINISTRATION HAS RESTORED NASA AERONAUTICS FUNDING TO A LEVEL THAT REFLECTS THE IMPORTANCE

PLACED ON IT BY THE POLICY. LET ME MENTION THREE IMPORTANT INITIATIVES THAT WERE PART OF THAT NEW EMPHASIS. INCLUDED ARE SUPPORT FOR ADVANCED COMPOSITE STRUCTURES TECHNOLOGY, AND TECHNOLOGY FOR NEXT-GENERATION ROTORCRAFT. ANOTHER IS THE NUMERICAL AERODYNAMIC SIMULATOR, WHICH WILL PROVIDE A NEW CAPABILITY TO ANALYZE THREE-DIMENSIONAL FLOW FIELDS AROUND ENTIRE AIRCRAFT; TODAY THIS CAN ONLY BE DONE THROUGH WIND TUNNEL AND FLIGHT EXPERIMENTS.

IN SPITE OF THE PROGRESS MADE IN THE PAST YEAR, WE STILL HAVE MUCH TO DO. WHILE THE GOALS AND OVERALL DIRECTION OF OUR CURRENT RESEARCH AND TECHNOLOGY PROGRAMS ARE GENERALLY APPROPRIATE AND CONSISTENT WITH THE TECHNICAL ASPECTS OF THE POLICY ANNOUNCED LAST YEAR, WE CAN STILL DO MORE TO DEVELOP MORE AGGRESSIVE AND IMAGINATIVE NATIONAL VISION TO GUIDE AERONAUTICS RESEARCH AND TECHNOLOGY FOR THE REMAINDER OF THIS CENTURY. ULTIMATELY WE MUST FOCUS MORE ON TRULY LONG-TERM, HIGH-RISK RESEARCH AND TECHNOLOGY--AREAS OF POTENTIAL TECHNOLOGICAL BREAKTHROUGHS, REVOLUTIONARY NEW SYSTEMS, AND ADVANCED CONCEPTS. AND WHILE WE MUST ALSO MAINTAIN A STRONG RESEARCH AND TECHNOLOGY BASE ACROSS DISCIPLINES, WE HAVE TO BE CAREFUL NOT TO DILUTE OUR LIMITED RESOURCES BY TRYING TO CHASE EVERY OPPORTUNITY. WE HAVE TO BE SELECTIVE; WE HAVE TO CONCENTRATE ON HIGH-PAYOFF AND HIGH-LEVERAGE TECHNOLOGY AREAS--AREAS, FOR EXAMPLE, LIKE COMPOSITES, NEW DESIGN CONCEPTS, INTEGRATED ACTIVE CONTROLS, ADVANCED PROPULSION, AND NUMERICAL SIMULATION.

BUT WE ALSO MUST REMEMBER THAT AIRCRAFT OF ALL KINDS ARE BECOMING MORE COMPLEX. SO WE'RE GOING TO HAVE TO LOOK BEYOND ADVANCES IN THE TRADITIONAL AERONAUTICAL DISCIPLINES ALONE. THE IMPORTANT PAYOFFS--IN TERMS OF SUPERIOR AIRCRAFT--WILL COME FROM UNDERSTANDING HOW TECHNOLOGICAL ADVANCES IN THOSE INDIVIDUAL DISCIPLINES--SUCH AS AERODYNAMICS, OR MATERIALS AND STRUCTURES, OR PROPULSION, OR OTHER FIELDS--INTERACT WITH ONE ANOTHER. OUR CHALLENGE FROM NOW ON IS TO UNDERSTAND HOW TO INTEGRATE THESE TECHNOLOGIES TO ACHIEVE LARGE ADVANCES IN SYSTEMS CAPABILITY. IN FACT, THIS INTEGRATION WILL PLAY AN INCREASINGLY IMPORTANT, IF NOT DOMINANT, ROLE IN THE DEVELOPMENT OF FUTURE MILITARY AND CIVIL AIRCRAFT. I WOULD SUGGEST THAT WE NOW HAVE TO CONSIDER THIS UMBRELLA OF SYSTEMS INTEGRATION AS A TRUE NEW TECHNICAL DISCIPLINE--AND MAYBE THE MOST IMPORTANT OF ALL.

LET ME OFFER AN EXAMPLE. ADVANCES IN STRUCTURAL CONCEPTS AND IN NEW MATERIALS CAN NOW PERMIT US TO DESIGN UNIQUE, AERODYNAMICALLY EFFICIENT CONFIGURATIONS THAT WERE SIMPLY IMPOSSIBLE BEFORE. BUT THOSE NEW CONFIGURATIONS THEN REQUIRE REDESIGNS OF THE PROPULSION SYSTEM, FLIGHT CONTROLS, AND AIRCRAFT SUBSYSTEMS--WHICH

IN TURN AFFECT THE DESIGN. THE REAL PAYOFF COMES IN OPTIMIZING THE WHOLE SYSTEM, AND ONLY THROUGH NEW INTEGRATED APPROACHES WILL WE BE ABLE TO FULLY TAP SOME OF THE GREAT POTENTIAL OPPORTUNITIES INHERENT IN DIVERSE TECHNICAL ADVANCES.

SUCH PROGRESS WON'T COME EASILY. IT DEMANDS A NEW SENSITIVITY AND A NEW APPROACH TO RESEARCH AND TECHNOLOGY--FROM BOTH A TECHNICAL AND MANAGEMENT STANDPOINT IN GOVERNMENT, INDUSTRY, AND THE UNIVERSITY COMMUNITY. THE PROGRESS WILL ALSO REQUIRE A COST-EFFECTIVE PROGRAM OF GROUND SIMULATION AND A WELL-ORGANIZED FLIGHT RESEARCH PROGRAM--POSSIBLY INCLUDING THE USE OF EXPERIMENTAL RESEARCH AIRCRAFT.

FINALLY, HOW WELL WE MEET OUR NATIONAL AERONAUTICS OBJECTIVES--AS WELL AS THOSE OF OTHER ADVANCED TECHNOLOGY AREAS--DEPENDS ON HOW WELL WE ADDRESS A MORE IMPORTANT AND BROADER PROBLEM--THAT OF ASSURING ENOUGH QUALITY SCIENTIFIC TALENT TO SUPPORT U.S. INDUSTRIAL AND GOVERNMENT NEEDS. HERE, WE ARE IMPEDED NOT ONLY BY THE INSUFFICIENT NUMBER OF STUDENTS ATTRACTED TO STUDIES IN THE FULL SPECTRUM OF AERONAUTICS-RELATED DISCIPLINES, BUT ALSO BY THE WEAKNESSES OF THE U.S. TECHNICAL EDUCATION SYSTEM THAT HAUNTS US FROM THE UNIVERSITIES RIGHT DOWN TO ELEMENTARY SCHOOL.

Mr. Chairman, I realize the well-known problems in science and mathematics education aren't the focus of these hearings, so I won't dwell on them. In fact, I have on other occasions shared my views with the full Science and Technology Committee. But I do want to make the point that we really can't talk about the future of aeronautics, or of virtually any other field of technology, without recognizing the impacts of technically trained personnel. In the long run, aeronautics preeminence will depend on the productivity and creativity of the work force--and that runs throughout our organizations, from the managers to the researchers and design engineers to the production supervisors to the people with their hands on the machinery.

As I mentioned at the outset, we have unparalleled expertise and capability in aeronautics, and there is much to do. The current fiscal environment, with its recognized limitations on staff and funding resources, challenges our national resourcefulness and creativity. In the near-term, we must adopt a more adventurous approach--be willing to take some risks on potentially high-payoff technologies--and we must continually re-examine our federal missions and priorities to make sure we allocate resources as wisely as we can. This is one of the greatest management challenges facing us today.

But we can't let our shorter-term needs distract us from the need for long-term growth and development in aeronautics. And here we require creative leadership, dialog, and commitment from the entire aeronautics community. Moreover, if we want to increase national effort, then we should also take a hard look at such actions as encouraging greater cooperation with industry in our federal research programs, IR&D ceiling, removing unreasonable anti-trust barriers, and improving tax incentives for private sector R&D and investment for increased productivity.

Based upon the Committee's recommendations to me, I've requested that NASA and DoD convene with industry and the university community to develop a visionary outlook for the state of aeronautics in the year 2000. Their task is to assess the optimal research and technology development path, facilities, and resources needed to achieve this vision. I've asked them to identify the most important and highly leveraged areas of technology advancement, those that should be pursued most vigorously, and to point to potential new directions and emphases in our aeronautical research and technology plans.

I expect the results of this long-range assessment, which should be completed within the next six months, TO BE AN IMPORTANT ELEMENT IN DETERMINING NEW DIRECTIONS AND EMPHASES IN U.S. AERONAUTICAL RESEARCH AND TECHNOLOGY PLANS.

MR. CHAIRMAN, THIS COMPLETES MY FORMAL STATEMENT. I WOULD BE PLEASED TO ANSWER ANY QUESTION YOU HAVE.

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Mr. GLICKMAN. Perhaps it would be better to hear from Mr. Steiner first, since you have been basically working together. Do you want—if you have to leave, though, we will get to questions with you first. When do you have to leave?

Dr. KEYWORTH. I have got to be back at 11:15.

Mr. GLICKMAN. OK, why don't we go ahead and ask you questions then, Mr. Keyworth.

Under what circumstances is funding of experimental—of an experimental research aircraft an appropriate Government role?

Dr. KEYWORTH. I think there are, just as there have been, a number of opportunities where it is a very appropriate role. However, I would caution that development of an experimental aircraft carrying all the way into the flight program can consume very large funding increments.

And it's a judgment question. Just as major new facilities are in any other area of technology development, certainly where there are major important breakthroughs both for new technology development for the commercial arena, as well as for a military arena, there will be—there will continue to be major need for new experimental aircraft.

I think with each and every opportunity we have to make a judgment and weigh the opportunities there relative to other disciplinary advances.

Mr. GLICKMAN. Well, we funded the tilt-rotor program, which was in a sense an experimental research airplane, wasn't it?

Dr. KEYWORTH. Yes, and I think that's a good example of an opportunity that was seized and clearly is paying off today, both—and I am particularly thinking of projected military requirements in the not very distant future.

Mr. GLICKMAN. Do you see any problem in getting appropriate cooperation between the Defense Department and NASA in terms of allocating resources if we were to move ahead on a research airplane program?

Dr. KEYWORTH. I think there have been some very excellent cooperations in the past, and there are continuing to be, but I certainly would emphasize that I believe an even better partnership between NASA, the Department of Defense and, most importantly, between the industries representing the pertinent technology base has simply got to be—got to be promoted and emphasized.

That's one of the things that I hope the standing committee that Jack Steiner chairs will be able to help us with.

Mr. **Glickman**. I agree. I happen to believe that the respective roles of NASA and DOD particularly are not as well defined in aeronautical technology as they should be and that as we look at limited resources, we may be able to find some of those additional resources if we redefine roles a bit better. And so I look forward to a better definition in that area.

But let me ask you this. Is the level of NASA's aeronautical budget adequate to achieve the kind of technical advances you spoke about?

Dr. **Keyworth**. Yes. Actually, we've looked at it very carefully both last year and in the ongoing budget process this year, and I believe it is a healthy level of effort. But I believe—and I said that there were—in my testimony that there were serious and difficult management challenges before us today.

I think in NASA, just as in most other Federal agencies that, let us say, are mature, I think we've got to pay considerable attention to exactly how effectively each and every dollar and each and every resources—that means manpower resources—is being used.

And I think having a clear goal by the end of the century and trying to lay a strategic path to get there is the primary aid to being able to improve our utilization of resources.

Mr. **Glickman**. OK, but when you talk about a clear goal, I want to make sure that we realize that we don't have all the answers in hand at the time we want to go ahead and do our research. That's the kind of reverse thinking that will not get us ahead of the Japanese, the Germans or even ourselves.

Dr. **Keyworth**. I've tried to emphasize in my testimony boldness. I meant it quite seriously when I said I think we are on the frontier of a renaissance in aeronautics technology. We can look forward at the end of the century or the beginning of the next to I think drastically new aircraft, and I believe we are going to have to make tough priority decisions now on exactly what areas of technology development will get us there most rapidly.

I perceive a goal that is as clear as can be, and that is, that the United States will maintain clear superiority in both civil and in military aircraft, that that is absolutely essential for our economic position, as well as for our military position.

Mr. **Glickman**. And I am basically telling you that I don't think we can do that without having some sort of ongoing research airplane program. I think that the post-World War II research airplane program led to unprecedented advances in aeronautics, and when we went to a very limited flight research program, particularly in the civilian sector, we have seen at the most very incremental progresses—progress in aeronautics.

Now, a lot of that has been unrelated to research. It's been financial. It's been a variety of things. But I think it has largely been based upon the fact that there has been no strong coordinated flight research program on behalf of the Government.

I think that NASA has gotten into a little bit of a trap of just doing basically what I call very incremental research in the process, and I would hope that your office would be open to a much enlarged flight research program to realize the kind of technical advances of which you spoke because without it, I don't think we are going to reach those great advances in order to maintain and continue military and civilian superiority in the rest of the world.

Dr. **Keyworth**. Research aircraft will certainly continue to play a major role, but let us not lose sight of the enormous breakthroughs that have been made in simulation and in wind tunnel tests that we can perform and diagnose today.

And also, we must remember that the major advances to be made that we can predict now are to achieve an aircraft that has the bulk of its metal replaced with composites, that has incorporated new propulsion technology and, as I emphasized in my prepared testimony, uses the full fruits of digital technology in a completely integrated electronics system.

Now, those must be pushed, those must be pursued, and a comprehensive program that is bold and puts emphasis on some of the high-risk areas where we can expect breakthroughs are critical. But I will conclude by saying that I thoroughly agree with you. We are going to have to look very carefully at where we need to put emphasis in research aircraft specifically to gain experience we can't gain any other way.

Mr. **Glickman**. Yes, I just close by—I mean, I agree you have to do the simulation, the wind tunnel testing. Tomorrow we are going to be dedicating a new wind tunnel down at the NASA Langley laboratory, but I would like to repeat what former NASA Administrator James Webb said. He said:

> Flight testing of new concepts, designs and systems is fundamental to aeronautics. Laboratory data alone and theories based on this data cannot give all the answers. Each time a new aircraft flies, a moment of truth arrives for the design, as he discovers whether a group of individually satisfactory elements add together to make a satisfactory whole, or whether their unexpected interactions result in a major deficiency. Flight research plays the essential role in assuring that all the elements of an aircraft can be integrated into a satisfactory system.

And I guess what I am saying is is that I think Mr. Webb had a lot of foresight in that statement, but flight research is also very expensive, and I guess that if we want to make that leap into becoming and continuing to be the greatest producers of airplanes in the world, we are going to have to pay the cost for it.

Mr. Carney.

Mr. **Carney**. Thank you.

Dr. Keyworth, you said in your opening statement that you support long-term, high-risk programs, but you also add high payoff. Isn't that somewhat contradictory?

Dr. **Keyworth**. I think that question addresses the very essence of what I would call basic or fundamental research. I think scientists and engineers are quite capable of identifying areas that represent hurdles to a major step forward in achievement. And today I think we can define a lot of hurdles that prevent us from moving from a 20-percent to an 80-percent composite aircraft, for example.

The payoff is identified, and it's huge. How you get there and which path you take to get there is the part that is associated with high risk. No, I think high risk and high payoff are quite compatible and I think this country has seen a tradition, especially in the postwar years, of taking high-risk steps that paid off with 100 to 1 type of benefits.

Mr. CARNEY. Well, in the climate that we have today, with limited resources, particularly financial resources, don't you see it a problem where we can't realistically expect to find support for high research—for high-risk research?

Dr. KEYWORTH. I think we've got to do our very best to articulate the importance of maintaining leadership, the fact that we are in a more competitive era than we have been in many a decade and the fact that we need all the more to use the very best of our ingenuity and innovativeness.

I believe that means taking risks, and I think that's also why we are looking today to the entrepreneur to build our future economy.

Mr. CARNEY. Well, that's a question I asked of General Yeager before. The fact is that we seem to be interfering with the entrepreneur or industry itself by having NASA do so many of the programs, though. We are removing the incentive from individual aircraft companies from going forward with some R&D.

Dr. KEYWORTH. Mr. Carney, you are defining, of course, the reason why we initiated an aeronautics policy in the first place. We felt very strongly that the line that defines the Government's and private sector responsibility needed to be far better defined than it was when President Reagan came into office.

We have attempted to do that, keeping in mind the fact that the Government is a major beneficiary of technological advances in aeronautics because of its military requirements.

But I certainly emphasize that we must push for and stimulate as much cooperation as possible and that industry must not feel as though the Government will step in and carry out its R&D responsibilities, and that line of demarcation must be discussed with industry and must be agreed upon and clearly envisioned by both sides.

Again, I think that's one of the roles that the committee that Jack Steiner chairs can play and is actually playing.

Mr. CARNEY. Thank you, Doctor. I realize that you have to be downtown in less than 35 minutes. With today's technology, that might be somewhat difficult, so I will yield back the balance of my time to the Chair.

Mr. GLICKMAN. Dr. Keyworth, we thank you. I remember the old Virginia Slims ad, where it says, "We've come a long way, baby," and OSTP, your office, has come a long way on this whole issue of aeronautics. Perhaps Mr. Steiner and others have been very influential on you.

Would you say that other aspects of the executive branch of Government, like the Office of Management and Budget, fully echo your comments that you made today.

Dr. KEYWORTH. I think that the Office of Management and Budget shares my objectives, seeing continued sustained U.S. leadership in aeronautics. I also would contend that from the—from my arrival in Washington and the earliest discussions that I had with you, I don't think you have seen any remarkable transition.

I continue to feel that our leadership is essential and that our country has come to expect bold steps in all of our industries and in our demonstrations of technology. How we get there does, I think we would all agree, require fiscal responsibility when the country is being seriously threatened by an emerging deficit.

But it is all a matter of judgment. I think that is what we are here for and that is what you're here for.

Mr. **Glickman**. And choices—and choices that can be made within existing priorities. And I realize that there is going—there are continuing battles that exist in the administration, as well as in Congress, as to whether—let's say we'd go ahead with a new supersonic flight research program that validated supersonic concepts.

And I know that there are a lot of people who opposed that in the past that would give us difficulties, that it would have to justify it in great depth. But at least from your standpoint I must commend you that you have, so to speak, honored your part of the bargain when we have spoken many times before and you have listened to the advisory committees, you have listened to the private sector.

And here was a case where the private sector has come to you and in many cases urged a more aggressive role for government, at least in the front end, the R&D side of the picture, and you just haven't ideologically and blindly said no to that. Some would find that unusual for this administration. However one would characterize it, I think it's an important statement that you've made.

Dr. **Keyworth**. I take as my model President Reagan but, in addition, let me point out that in my own opinion, I think the most innovative and stimulating and strongest leadership that this country has seen today is coming from the private sector, a private sector that has responded in the last few years to the challenges that we are facing from Japan, from Western Europe, and from more technologically advanced trading partners. I think their dynamism, I think their innovativeness is what is making this country a vibrant Nation today

Mr. **Glickman**. And we also realize that the aviation industry as a whole has had a tremendous partnership with Government over the last 30 years in the military sector and with respect to NASA. So, therefore you cannot only build upon your private sector innovation but realize that we have an industry that has had a partnership with Government and it's been a useful one, as well.

Dr. **Keyworth**. Only emphasizing that Government has a lot more to learn from industry than industry has to learn from Government.

Mr. **Glickman**. I suppose we could continue this exchange back and forth, but I appreciate your being here. Thank you very much, Dr. Keyworth.

Mr. Steiner, why don't you move to the center there. We appreciate very much your work, your influence on Dr. Keyworth, as well as others, and the fact of your enormous interest in this whole subject matter.

Mr. **Steiner**. I have the greatest of admiration for Dr. Keyworth, and I am not sure I influenced him. I helped him.

Mr. Chairman and members of the subcommittee, this subcommittee's hearings over the last several years provided the Government a very constructive and cohesive balance on the future needs and opportunities of U.S. aviation. Your focus on the future is key, sir, and had the attention of Congress and the Nation been so tempered in earlier decades, I do not believe the Nation would have seen the depth of the uncertainties that we struggle with today.

My purpose in accompanying Dr. Keyworth, of course, is to provide some additional insights on the Aeronautical Policy Review Committee's first year assessments of implementation progress. It has been a privilege and an honor for me to chair this group of 16 nationally recognized leaders who, I can assure you, approach their task with the same spirit of national objectivity that marked the policy's study and creation under Dr. Keyworth's leadership.

As Dr. Keyworth noted, the implementation review covered the current long-range R&T plans of NASA and DOD, examining the overall directions and adequacy for the timely attainment of vital national goals.

Timeliness is crucial since major aspects of the Nation's strategic and economic security—and they are linked, of course—are highly linked to the readiness of the Nation's aeronautical technology by the end of this century, just 16 years from now. Our committee's recommendations largely address this vital aspect and also the national barriers that have slowed U.S. progress.

I will cover technology quickly. The sobering statement that Dr. Keyworth made that all aircraft currently operational, either military or civil, could be technologically superseded by the year 2000 is illustrative of the advancement potentials in the window today. Let me identify a few of those parts which by their integration form the quantum underlying his observation.

The airplane's heaviest weight, of course, is centered in the primary load-bearing structural parts that make up the fuselage, wing torque box, empennage, engine mounts and similar elements. The fabrication of such parts from advanced composite materials could reduce the structural component weights by 25 to 35 percent. However, significant additive weight reductions to this would be derived from the synergistic benefits from iterative design, reduced engine size, and the integration of other complementing advancements.

The full exploitation of breakthroughs in structural advancements, metallic and nonmetallic, requires that we optimize fabrication processes for life cycle quality assurance and costs. This accomplishment is particularly crucial to the preservation of U.S. industrial leadership. It will require a long leadtime and vast capital investments by the industrial base, both of which are gated by research progress made over the last few years.

New potentials in control systems concepts that involve electronic integrations, artificial stabilization, variable camber without separate control, all-electric controls, fiber optics that could replace much of the heavy complex of today's airplanes are parts of the integrative advancement potentials. Some of these will further military stealth objectives, and most will have civil and military significance.

When technologies of this nature combine under a framework of new materials, they will unquestionably obsolete present state of the art aircraft. It is within the realm of feasibility that by the year 2000 either the United States or its competitors will lead by exploiting such potentials to produce aircraft of either half the size or weight or double the range performance of present day vehicles.

Propulsive systems advancements figure heavily in this possibility. The door is opening on a series of new subsonic hybrid engine potentials that lie between the conventional turbofan and turboprop engines. Hybrids could be geared/ungeared, ducted or unducted. New materials, including ceramics, electronic integrations, and control concepts are part of these developments. The committee believes that such possibilities also prevail at supersonic and hypersonic regimes and the total could produce quantum leaps in propulsive efficiency.

Specialized vehicle task requirements will capitalize on other potentials that are equally visible. Cruise missiles, fleet air defense weapons, vehicles operating in transatmospheric environments, and remotely controlled air vehicles can all similarly benefit. There are substantial reasons to advance and improve STOL and VTOL capabilities. Airport ground constraints figure into future civil needs, and runway denial underlies the military requirement.

The total implies a national situation where potentials exceed resources. In view of this, the committee has recommended that the most important and highly leveraged research areas receive greater focus. Certain research tasks must be addressed at significantly higher continuity. Technology readiness is the key in this respect.

Before design applications can be made, a body of knowledge must be accrued that exposes the risks and their acceptability levels. It must also include in-depth evaluations of all of the available alternatives in design and production.

Programs are far too expensive and irreversible to be based on anything but the very best alternative in each of the technological areas. Thus, the body of knowledge will be as a bed of bricks, some of which are useful as foundations for refinement of the final technology selected, while others will be used to identify the weaknesses in alternatives that eventually prove to have unacceptable risk balances.

Effective readiness attainment is a very long leadtime task which preempts specific application objectives. The Government's requirement for an audit trail linking the final system downward step by step to the particular bricks in the bed I've described can only be based on an attempt to micromanage a process without understanding it.

This has placed a very costly top-down constraint on what is logically the reverse, a bottom-upward process of building. Seldom is it fully recognized that failures, delays, and cost overruns in military developments have been preordained because requirements of this nature short circuited an adequate job of technology readiness.

Dr. Keyworth commented on the significance of understanding integration. This is vital if we are to optimize a national benefit from the individual advancements. The integrative process has become vastly more complex and not only must the most advantageous usage be determined for each technology, but the most advantageous integrated solution for systems, components, and the total vehicle must be determined as well.

In addressing readiness attainment and systems integration, the role of the experimental flight vehicle was underscored by the committee. The committee felt that such U.S. flight research programs must be revitalized if we are to preserve or, in some cases, regain technological preeminence in vehicle systems or final products.

Let's talk for a moment about roadblocks. Aircraft could appear as vastly different vehicles beyond the year 2000. We should anticipate some radically different operational and mission concepts for both military and civil vehicles of all types and sizes. Without adequate visualization of these potentials and their benefits, the total of U.S. aviation leadership is at risk.

Our review has exposed the fact that there is a relative lack of truly long-term vision framing aeronautical R&T today. Nationwide, we've drifted, as you mentioned, by the way, into acceptances of incremental improvement with very little consideration beyond timing of the next generation of aircraft which this may produce.

We cannot assume this path to sustain preeminence for the simple reason that we are already at risk. Competing nations are fully aware that U.S. preeminence could become vulnerable to their increased pace. In fact, they've been aware of it for the last 10 years.

The Nation must elevate its technological sights above the framework of R&T programs as they are presently conducted. Exploratory and conceptual developments, for example, were recognized by the committee as weak elements. This is why the committee recommended that NASA and DOD convene with industry and the academic communities to draw a visionary framework of what the known potentials could achieve by 2000.

We've recommended that this be done within the next 6 months. I would expect this effort also to produce some missing links, possible areas where potentials or priorities yet unknown or unidentified may become crucially significant to leadership preservation.

The committee is pleased that Dr. Keyworth has already, just in the few days since the report came out, acted upon this vital need. It is a critical first step in establishing America's aiming points for the 21st century preeminence.

Throughout America affordability has leaped into our minds as an insurmountable issue, one that would reduce the quality of American life today and one that holds serious consequences for America's world status in the coming century.

Personally, Mr. Chairman, I believe that affordability has existed as a major barrier to U.S. aeronautical advancement for well over a decade. Its presence is why the pace of U.S. advancement slowed. This is why we've not had a cohesive and imaginative national vision for aeronautics, one that drives the programmatic steps toward advancement rather than being driven by them.

Affordability is a value judgment, and in this sense the preservation of American preeminence requires that Congress, and indeed all of the Nation, come to grips with the judgments that have been made. However, the committee also observed that responsible levels in Government and Congress must also recognize the degree of continuity in research development and production, military or civil, strongly interacting to influence costs at all levels of the advancement process.

In many ways the problems of affordability add up to nationally imposed barriers. Government sponsors of aeronautics are unable or unwilling to risk seeking approvals for long-term advancements under acquisition and authorization systems which focus attention on near-term priorities and budgets.

The aircraft industry is similarly constrained with respect to nontechnical areas of Government policy which affect the private sector's development, risk decisions, and cost. The point that the committee wishes me to convey, Mr. Chairman, is that while affordability is a complex problem, it is largely solvable by removing the barriers. It may become unsolvable if we continue to let them stand.

Let's talk about synergy. Let's for one moment consider the implications of the affordability barriers from a much broader value context. The technological and skill base required for the advancement of civil and military aeronautics is solidly fused in commonalities. U.S. aviation synergies are frequently not recognized as useful and powerful forces on costs, continuity of effort, and risk decisions.

The real seat of synergistic power for the U.S. industrial preeminence is centered in the 15,000 company supplier base which supports the airframe builders. Civil work forms approximately 60 percent of the aircraft base for these companies, providing a crucial balance in wartime surge capacity that is maintained by the private economy without govenment funds.

Civil competitive drive enhances affordability. It stimulates the sustained placement of up-front capital for technology advancements, modernizations, and productivity improvements that keep the whole of the U.S. aeronautics competitive.

Policy decisions which weaken either side, civil or military, impair the synergistic linkage and will ultimately make U.S. aircraft less affordable. Consequently, Mr. Chairman, a civil industry impairment will in time reflect increased military costs and, of course, the reverse is true as well.

In summary, in a significant manner the nine specific recommendations that the committee has passed on to Dr. Keyworth are intended to bring the present plans and their timing into a cohesive national base of execution which will secure and preserve U.S. aeronautical preeminence into the 21st century.

We are fortunate that the Nation has in place a well established research foundation that is capable of securing this vital national objective. Also in place is a clearly defined framework of roles and responsibilities under which the aeronautics research partnership between Government, industry, and academia can flourish and improve.

Our committee findings did not suggest change to these vital aspects. We did, however, recommend specific mid-course actions in R&T and urge serious consideration of major roadblocks that threaten to impede U.S. progress. The committee believes that both areas will need creative attention for attainment of complex and challenging research objectives in our difficult fiscal environment.

Finally, Mr. Chairman, let me emphasize the committee's concern that our Nation must face the need for growth in national effort in major technology areas. Reallocation of current resources alone may not be sufficient and also increases in Government funding may not be the solution that we most need.

We believe that there are alternatives in creative policy and research management that can bridge much of the affordability gap and put the future within our grasp. This is not wishful thinking. It is a vital necessity for our success.

Mr. Chairman, that concludes my official statement. I'd welcome questions and answers.

[The prepared statement of Mr. Steiner follows:]

Statement by
John E. Steiner

Before

Committee on Science and Technology
Subcommittee on Transportation, Aviation and Materials
U.S. House of Representatives

December 5, 1983

Mr. Chairman and members of the Subcommittee:

INTRODUCTION

The record will show, Mr. Chairman, that this subcommmittee's hearings over the past several years have provided government a very constructive and cohesive balance on the future needs and opportunities for U.S. aviation. Your focus on the future is key, Sir, and had the attention of Congress and the nation been so tempered in earlier decades -- I do not believe that the nation would have seen the depth of uncertainties that we struggle with today.

My purpose in accompanying Dr. Keyworth is to provide some additional insights to the Aeronautical Policy Review Committee's first year assessments of implementation progress. It has been a privilege and honor for me to chair this group of 16 nationally recognized leaders who, I can assure you, approached their task with the same spirit of national objectivity that marked the policy's study and creation under Dr. Keyworth's leadership.

As Dr. Keyworth noted, the implementation review covered the current long-range R&T plans of NASA and DOD...examining the overall direction and adequacy for the timely attainment of vital national goals. Timeliness is crucial, since major aspects of the nation's strategic and economic security are highly linked to the readiness of the nation's aeronautical technology by the end of this century...just 16 years from now. Our Committee's recommendations largely addressed this vital aspect, and also the national barriers that have slowed U.S. progress.

TECHNOLOGY POTENTIALS

The sobering statement by Dr. Keyworth -- that all aircraft currently operational, either military or civil, could be technologically superseded by year 2000 -- is illustrative of the advancement potentials in the window today. Let me identify some of the technological parts which, by their integration, form the quantum underlying his observation.

Structural Materials: The airplane's heaviest weight, of course, is centered in the primary load bearing structural parts that make up the fuselage, wing torque box, empennage, engine mountings and similar elements. The fabrication of such parts from advanced composite materials could reduce structural component weights by 25 to 35 percent. However, significantly additive to this would be the synergistic benefits from iterative design, reduced engine size, and the integration of other complementing advancements. The full exploitation of break-throughs in structural advancements (both non-metallic and metallic) requires that we optimize the automated fabrication processes for life cycle quality assurance and costs. This accomplishment is particularly crucial to preservation of U.S. industrial leadership. It will require a long lead time and vast capital investments by the industrial base, both of which are gated by research progress made over the next few years.

Control Systems: New potentials in control concepts that involve electronic integrations; artificial stabilization making possible a smaller wing and tail; variable camber without separate control surfaces; all-electric controls that replace much of today's hydraulics and control cable systems; and fiber optics that could replace much of the heavy complex of wiring in today's airplanes are all part of the many integrative advancement potentials. Some of these will further military stealth objectives, and most have both civil and military significance. When technologies of this nature combine under a framework of new materials they will unquestionably obsolete present state of art aircraft. All contribute to reducing the total weight and size of the air vehicle, and as the aircraft for a given military or civil job gets smaller, it becomes less expensive to build and operate. It is within the realm of feasibility that by year 2000, either the U.S. (or its competitors) will lead by exploiting such potentials to produce aircraft of either half the size or weight or double the range performance of present day vehicles.

Propulsion: Propulsive system advancements figure heavily in this possibility. The door is opening on a series of new subsonic hybrid engine potentials that lie between the conventional turbofan and turboprop engines which the industry has today. Such hybrids could be geared or ungeared, and either ducted or unducted. The new materials (including ceramics), electronic integrations and control concepts are part of these developments. The Committee believes that such possibilities also prevail at supersonic and hypersonic regimes, and the total could produce quantum leaps in propulsion efficiency. Their development will be complex, and the potential candidates for development must be narrowed to the most promising before major national efforts are approached. Nonetheless, getting to this point will require increased levels of research over most of this decade.

These new concepts in materials, controls and engines are significant examples that will figure in many future air vehicle applications. However, specialized vehicle task requirements will capitalize on other potentials that are equally visible. One such match could be the advancement of mechanical or natural laminar flow to improve the performance capability of military stand-off weapon systems or specialized patrol missions. Substantial aerodynamic improvements can be expected to benefit hypersonic vehicles operating in transatmospheric environments for intercept missions or other military objectives. Cruise missiles, fleet air defense weapons and remotely controlled air vehicles can all similarly benefit. There are substantial reasons to advance and improve STOL and VTOL capabilities. Airport ground constraints figure into future civil needs and runway denial underlies the military requirement.

Levels of Effort: The total implies a national situation where potentials exceed resources. In view of this the Committee has recommended that the most important and highly leveraged research areas receive greater focus . Certain research tasks must be addressed at significantly higher continuity if preeminence is to be preserved. Technology readiness is key in this respect.

Before design applications can be made, a "body of knowledge" must be accrued that exposes risks and their acceptability levels. This knowledge, as noted earlier, must include the manufacturing process risks. It must also include in depth evaluations of the available alternatives in design and production. Programs are far too expensive and irreversible to be based on anything but the very best alternative in each of the technological areas. Thus the body of knowledge will be as a bed of bricks, some of which are useful as foundations for refinements of the final technology selected while others will be used to identify the weaknesses in alternatives that eventually prove to have unacceptable risk balances.

Effective readiness attainment is a very long lead-time task which preempts specific application objectives. The government's requirement for an "audit trail" linking the final system, downward step by step, to the particular bricks in the bed I've described, can only be based on an attempt to micro-manage a process without understanding it. This has placed a very costly top-down constraint on what is logically the reverse -- a bottom-upward process of building. Seldom is it fully recognized that failures, delays or cost-overruns in military developments have been preordained because requirements of this nature short-circuited an adequate job of technology readiness.

Dr. Keyworth commented on the significance of understanding integration. This is vital if we are to optimize a national benefit from the individual advancements. The integrative process has become vastly more complex, and not only must the most advantageous usage be determined for each technology, but the most advantageous integrated solution for systems, components, and the total vehicle must be determined as well. Hardware and software for literally hundreds of computers and processors must be made to work together for the benefit of the military or civil end product or system.

In addressing readiness attainment and systems integration, the role of the experimental flight vehicle was underscored by the Committee. Such a vehicle can be one which tests component technologies on available test beds, or it can be an all new flight article to explore the potentials of integrated technology and validate its risks in a far more affordable and timely manner than would be the case if committed to a final program. The Committee felt that such U.S. flight research programs must be revitalized if we are to preserve or in some cases regain technological preeminence in vehicle systems or final products.

ROADBLOCKS

Given the integrative potentials that I've just outlined, aircraft could appear as vastly different vehicles beyond year 2000. We should anticipate some radically differing operational and mission concepts for both military and civil vehicles of all types and sizes. Without adequate visualization of these potentials and their benefits, the total of U.S. aviation leadership is at risk, as I'll explain.

Vision: Our review has exposed the fact that there is a relative lack of truly long-term vision framing aeronautical R&T today. Nationwide, we've drifted into acceptances of incremental improvement with very little consideration beyond timing of the next generation of aircraft which this may produce. We cannot assume this to sustain preeminence, for the simple reason that we are already at risk. Competing nations are fully aware that U.S. preeminence could become vulnerable to their increased pace -- they've been aware of this for the last ten years.

The nation must elevate its technological sights above the framework of R&T programs as they are presently conducted. Exploratory and conceptual developments, for example, were recognized as weak elements. This is why the Committee recommended that NASA and DOD convene with industry and the academic communities to draw a visionary framework of what the known potentials could achieve. We've recommended that this be done within the next six months and that the task should also construct an optimal R&T path for readiness attainment by year 2000, along with assessments of the resources required. I would expect this effort to produce some "missing links" --possible areas where potentials or priorities yet unknown or unidentified may become crucially significant to leadership preservation.

The Committee is pleased that Dr. Keyworth has already acted upon this vital need. It is a crucial first step in establishing America's aiming points for 21st century preeminence. We've also recommended that the results of this effort be reviewed for further comment by the Aeronautical Policy Review Committee.

Affordability: Throughout America, affordability has leaped into our minds as an unsurmountable issue -- one that would reduce the quality of American life today and one that holds serious consequences for America's world status in the coming century. This, most of our Committee agreed, has become the number one priority for military and civil aviation -- how can we make airplanes more affordable.

Personally, Mr. Chairman, I believe that affordability has existed as a major barrier to U.S. aeronautical advancement for well over a decade. Its presence is why the pace of U.S. advancement slowed to the extent that many in government had wrongfully perceived the U.S. industry and its technology to be in their sunset. This is why we've not had a cohesive and imaginative national vision for aeronautics -- one that drives the programmatic steps toward advancement rather than being driven by them.

Affordability is a value judgment and in this sense, the preservation of American preeminence requires that Congress and indeed all of the nation come to grips with the judgments that have been made. Advanced manufacturing and product technology, materials and process developments are areas where affordability contributions can be made through technology. However, the Committee also observed that responsible levels in government and Congress must also recognize that the degree of continuity in research, development and production (military or civil) strongly interacts to influence costs at all levels of the advancement process.

In many ways, the problems of affordability add up to nationally imposed barriers. Government sponsors of aeronautics are unable or unwilling to risk seeking approvals for long-term advancements under acquisition and authorization systems which focus attention on near-term priorities and budgets. The aircraft industry is similarly constrained with respect to non-technical areas of government policy which affect the private sector's development risk decisions and costs. The point, that the Committee wishes me to convey, Mr. Chairman, is that while affordability is a complex problem, it is largely solvable by removing the barriers to affordability. It may become unsolvable if we continue to let them stand.

Synergy: Let's for one moment consider the implications of affordability barriers from a much broader value context. The technological and skill base required for the advancement of civil and military aeronautics is solidly fused in commonalities. From basic research through production, U.S. aviation synergies are frequently not recognized as useful and powerful forces on costs, continuity of effort and risk decisions.

The real seat of synergistic power for U.S. industrial preeminence in aeronautics is centered in the 15,000 company supplier base which supports the airframe builders and other major aerospace firms. Civil work forms approximately 60 percent of the aircraft business base for these companies, providing a crucial balance in wartime surge capacity that is maintained by the private economy --without government funds. The civil business, with greater expectations for production continuity more readily motivates investment than does the uncertainty of military aircraft business.

Civil competitive drive enhances affordability -- it stimulates the sustained placement of up front capital for technology advancements, modernizations and productivity improvements that keep the whole of U.S. aeronautics competitive. Policy decisions which weaken either side (civil or military) impair the synergistic linkage and will ultimately make U.S. aircraft less affordable. Consequently, Mr. Chairman, a civil industry impairment will in time reflect increased military costs and, of course, the reverse is true as well.

SUMMARY

In a significant manner the nine specific recommendations that the Committee has passed on to Dr. Keyworth are intended to bring the present plans and their timing into a cohesive national base of execution which will secure and preserve U.S. aeronautical preeminence into the 21st century.

We are fortunate that the nation has in place a well established research foundation that is capable of securing this vital national objective. Also in place is a clearly defined framework of roles and responsibilities under which the aeronautics research partnership between government, industry and academia can flourish and improve. Our Committee findings did not suggest change to these vital aspects. We did, however, recommend specific midcourse actions in R&T and urged serious consideration of major roadblocks that threaten to impede U.S. progress. The Committee believes that both areas will need creative attention for attainment of complex and challenging research objectives in our difficult fiscal environment.

Finally, Mr. Chairman, let me emphasize the Committee's concern that the nation must face the need for growth in national effort in major technology areas. Reallocation of current resources alone may not be sufficient and also, increases in government funding may not be the solution that we most need. We believe that there are alternatives in creative policy and research management that can bridge much of the affordability gap and put the future within our grasp. This is not wishful thinking --it is a vital necessity for our success.

Mr. GLICKMAN. Thank you.

First of all, the statement is excellent, it is in-depth, and I think it gives us a good understanding of where you've been and what recommendations you've made to OSTP.

We've talked a little bit today about entering an era where we would have a research airplane. I wonder if you might comment on the concept of the research airplane and how it would relate to some of the recommendations that you've made.

Mr. STEINER. A research airplane is a vital part of the construction of the bed of bricks that I mentioned. A research airplane should not be viewed as a prototype. It should be viewed as a means of getting at some of the bricks. In that context, a research airplane is stimulative, it is integrative, and it is very constructive. It is fairly expensive.

Now, the bed of bricks has to be constructed. I am very much in favor of research aircraft, but I'm not in favor of research aircraft at the expense of abandoning the bed of bricks. The audit trail idea through the particular bed of bricks is, as I mentioned, an idea that my experience, some 40 years in aeronautics, doesn't find any credibility in.

So that as the research airplane demonstrates the validity of combinations of the bed of bricks and acts as a synergistic element, I support it.

Mr. GLICKMAN. Do you think that an acceptable supersonic transport, commercial transport, could be developed?

Mr. STEINER. Certainly.

Mr. GLICKMAN. Should it be developed?

Mr. STEINER. Yes, it should be developed. The timing is a little uncertain in my mind and the priority has to be weighed against the priorities of other elements that let's say comprise our strategic and economic security.

I believe the SST should emerge. I believe it should take its place in the priority segment and that national strategic and economic security are our prime targets under which all that falls.

Mr. GLICKMAN. OK. Now, relate—specifically, when you are talking about national strategic and economic policy, what are you talking about now?

Mr. STEINER. I said security not policy, I believe.

Mr. GLICKMAN. I am sorry, security, yes.

Mr. STEINER. National and economic and strategic security means jobs, it means a proper military balance with the Soviets, it means ability to compete, both civilly and militarily with our industrial competitors, which are growing approximately as good as we are. So that I would place that basic objective as one that the supersonic transport has to fit into.

I believe the supersonic transport, however, could be part of the solution, not part of the problem. I think it could be part of the solution. I simply don't know what's——

Mr. GLICKMAN. Is it clear that—that none of our, at least allies, who are competitors of ours are in the process of moving ahead on an SST idea?

Mr. STEINER. I don't think that's clear. I think our competitors, be they civil or military, are looking for every possible way that they can leapfrog the United States, and the absence of a program on this airplane would be an obvious attraction.

Mr. GLICKMAN. You mentioned an increase of NASA funding. What levels could NASA use effectively?

Mr. STEINER. I'd like to answer that in a somewhat roundabout manner. In the first place, I would like Hans Mark to be asked that question when he's on the stand so that I don't detract in any way from his assessment of what NASA could use.

The second one is that I'd like to volunteer something that is not, let's say, blessed by anybody. Obviously, the opportunities are greater than the funding. There's no doubt about that.

I am attracted to a solution whereby the President of the United States challenges industry, NASA, DOD, academia to come up with a plan. I watched this happen in education only 1 year or 1½ years ago. The Department of Education triggered President Reagan's challenge with a study "A Nation at Risk." The mobilization of State and industrial money and effort that has followed is startling.

In the State of Washington alone, which is way up in the Northwest corridor, we have 34 companies working in a roundtable chaired by the head of the State's department of education to plow more money and effort into K to 12 and undergraduate and graduate education.

I would like to see the same sort of challenge made on aeronautics technology. I would then like to see NASA work as, let's say, the coordinator of that. And in that way, I would mention a couple of caveats. With these, I think you would have little trouble emulating the education example.

One is that industry has to be assured that the money that they put forth does not, in large part, go for bureaucratic administration. So the degree of bureaucracy involved cannot be 50 percent, or even 25 percent, it has to be lower to attract industry.

Second, there must be some protection of proprietary rights.

Third, it isn't good enough just to change the wording of the antitrust bill. One has to decrease the fear level of companies working together for a national goal enunciated by the President, and putting their money and their effort toward a common goal.

And fourth, it is very difficult to separate R&T and R&D. One should not try go draw a fence between the two, and admit that this national cooperative effort could span both R&T and R&D.

I believe I've answered your question in a different way than simply saying NASA should have its budget doubled. It doesn't need just that, it needs a heck of a lot more than doubling. The total funding necessary to accomplish the aeronautics objective I've enunciated is a lot more than NASA will ever get through the present budgetary process in the present fiscal environment.

Mr. GLICKMAN. Well, Mr. Steiner, you've issued what I consider to be a call to arms or a challenge to all of us, not only the legislative branch, but to the executive branch as well. I—I accept what you've said. I think it's necessary. And I am not sure that all segments of your industry accept that, neither am I sure at all that people, other than—maybe Dr. Keyworth does—but Mr. Stockman, I am confident, would not accept your premise right now, because it would involve Government much more actively, indirectly as well as directly, although, as you point out, you've got some ground rules there that will prevent it from taking over the process, so to speak.

But I agree with you. I think that if we are to leapfrog and not just respond to the Soviets or respond to the French, but move ahead, as we did for 15 years in this country, we're going to have to have that kind of maintenance of effort that—you mentioned about the education field.

But you've—we've come a long way, as I've said before. We've moved this government a bit in the last 2 or 3 years. There's no reason why we can't continue to try.

Mr. **STEINER**. Mr. Chairman, the power of this Nation when mobilized is prodigious. The educational example I mentioned, I believe, will go a longways toward correcting that difficulty in a period of several years. I believe the same thing can be done in any field, and aeronautics is one that warrants it.

Mr. **GLICKMAN**. You know, for example, I happen to serve on the Judiciary Committee, and we've been struggling with this joint research concept. But we really still don't have any clear policy by the administration as to what they want in legislation permitting joint research. It's not just their fault, it's a tough issue to deal with, because the thought hasn't been given to the problem.

And I think what you're saying is that we got to do some very critical and fairly expeditious thinking on it, and you're talking about doing it in the aeronautical field now—and Dr. Keyworth even mentioned that in his statement—in the next year.

Let me ask you one final question. What can we do to aid academia more. Do you think that U.S. industry can aid academia more than they're doing now, and what should we in government be doing in that area?

Mr. **STEINER**. Well, fortuitously, and as I mentioned, there's an awful lot going on in aiding academia right now. Now, I believe that the challenge that President Reagan issued, the publication of "A Nation at Risk," the mobilization of roundtables in many States, I believe it'll spread to every State before we're through.

I believe that attacks a much broader problem than some people address when they said aid academia and mean scholarships or doctorate theses. I believe our academic advanced technology situation exists from kindergarten through doctorate degrees. And I believe it has to be aided.

I believe industry is a source of aid, funding, expertise, funding in kind. There's lots and lots of ways. And I am overjoyed with what I see emerging from the so-called roundtables progetations. How does industry do more than just throw money over the fence? How do they actually aid? There's many, many ways that that can be done.

So my observation would be that we have not really tapped the aid to academia that industry can offer.

Mr. **GLICKMAN**. Thank you.

Mr. Carney.

Mr. **CARNEY**. Thank you.

Mr. Steiner, before you mentioned that we have to arrange our priorities and, in so doing, we have to give consideration to our economic well-being and our security. Part of our economic well-being, I would assume, would be that we have a—a very strong aviation industry in the civil side. And when asked if you think we should go forward with an SST or an AST, you said that the timing has to be considered to those two issues I mentioned, security and economics.

What would have a higher priority in civil transportation than the SST or the AST at this time? What would you suggest we should do right now in the area of civil transport aviation?

Mr. **Steiner**. I believe a higher priority—and I do not in any way wish to demean the SST as a program—but the highest priority is that we leapfrog the—leapfrog the world technology.

I mentioned three elements that can do that, composite structure, propulsive efficiency, and integrated digital electronics, everything from fly by wire to full-scale active controls to fiber optics.

I believe that bed of bricks to leapfrog the civil competition is first priority, because I believe if we don't erect the bed of bricks, the other people will, and we will find ourselves outclassed. There are many, many jobs that rest on that.

Mr. **Carney**. You seem to believe then that, particularly in the civil side, a program should be evolutionary in nature and not revolutionary in nature.

Mr. **Steiner**. Oh, I wouldn't call those things I just mentioned really evolutionary. If one is going to adopt composite structure, one has to address a multibillion-dollar manufacturing process and replacement of facilities. That's a revolution.

Mr. **Carney**. But you'd be talking about composites to take the place on an airframe—of a piece of equipment that's on an existing airframe; is that not correct?

Mr. **Steiner**. No, no. I'm talking about a whole new integrated airframe which is half the size or half the weight for the same job.

Mr. **Carney**. That is somewhat revolutionary, yes.

Mr. **Steiner**. Sure, that's revolutionary. That combines the three elements——

Mr. **Carney**. All right.

Mr. **Steiner** [continuing]. The structure, the propulsion, and assistance. I have to do that.

Mr. **Carney**. I see. Yes——

Mr. **Steiner**. I would call that revolutionary.

Mr. **Carney**. I'm glad you clarified that. It wasn't in my mind, quite honestly.

Mr. **Steiner**. If our committee was unanimous in one thing, it was unanimous that we should be more aggressive, bite off more. In other words, aim by 2000 to do the same job with half the weight of the airframe. That is an iterative process. You don't do it by replacing 767 wings. You do that by integrating a whole new airplane around a whole new set of factors.

Mr. **Carney**. Well, by using those three technologies, you very well could be moving into an SST or——

Mr. **Steiner**. Sure.

Mr. **Carney** [continuing]. Whatever. Or you could be staying in the same speed——

Mr. **Steiner**. Either one.

Mr. **Carney** [continuing]. And the range doesn't matter.

Mr. STEINER. Or—either one, or I would prefer for the Nation, both.

Mr. CARNEY. Right.

Let me ask you now in the military side. Did your committee deal with some of the needs of the military size, as far as where you think we should go?

Mr. STEINER. Yes, I would say the answer to that is positive. We dealt with the military side. As I say, in many areas, such as the three I mentioned—although they're not all the same and, of course, there are broad spectrums of military and civil—but in many cases, the technology is really the same. It is not possible to separate military technology from civil technology, except in payloads and a few other instances.

Furthermore, the power structure for doing this is in the 15,000 companies. And interestingly, the investment necessities for military and civil are not really a problem, in my opinion. The military is accustomed to not having up-front money. The civil is accustomed to having up-front money. That has to be rectified to some extent. The civil is accustomed to continuity of program; the military is not. That affects those 15,000 companies, and that's where the strength lies, and that's where the effort has to be expended.

Mr. CARNEY. I'll go back to my first question that I asked of General Yeager—or perhaps it was my last question—but we're looking at the forward edge of aviation and aeronautics.

Mr. STEINER. Yes.

Mr. CARNEY. How about the tail-end of that industry? As I said before, in some of the commercial areas now, we see an awful lot of foreign aircraft, particularly in the short-range aircraft to the small commuter, that type of thing, the Dash 7's, the Short Brothers planes, those types of things.

Did your committee look at that area of the industry and, if so, what recommendations did it come up with?

Mr. STEINER. We did not come up with specific recommendations, nor do I think one can make specific recommendations.

I will say this. If the bed of bricks that I have described has the body of technology from which aircraft are derived, is properly, let's say, amassed, and it includes manufacturing such that the cost of such an airplane—and you're aware that the airplane they're speaking of has a cost problem, has a serious cost problem because the—the requirements for flight are, in many cases, similar to those of larger and more expensive airplanes, and the customer base is emerging from the deregulated environment and, in many cases does not have the finances to buy airplanes without financial aid—I think the Government should look into that latter question: How do we get our customer base in the United States in shape to support our industry?

Mr. CARNEY. You become competitive.

Mr. STEINER. No. To support the industry. The customer base for the commuter airplane you're talking about can't buy an American airplane. It can buy a nicely subsidized foreign airplane. But maybe one should look at the impact of deregulation and the emergence of 200 commuter airlines and ascertain just how we get that base in shape to buy an American airplane.

Mr. CARNEY. Well, who has attempted to make an American airplane to compete in that area? What do we have that looks anything like a—let's say a Dash 7 or the smaller DeHavilland two-engine plane with 25, 30 seats?

Mr. STEINER. Oh, I'm sure you're well aware that Fairchild has a program partially financed by the Swedish Government.

Mr. CARNEY. If you're from Long Island, you are well aware of that, yes.

Mr. STEINER. My own feeling is that we should look to our system, both as to our customers' health and as to our technology readiness at low risk, or at minimal risk, and we should look inward rather than looking outward and saying we should subsidize in order to get sales against subsidized competition. We should look at what we can do within our culture, within our system. And I think there's plenty we can do to encourage U.S. manufacturers to build commuter airplanes, and I think those manufacturers, with the aid of the technology bed of bricks that I talked about, can build a better mouse trap than the foreign manufacturers can build.

Mr. CARNEY. Well, most of the technology that's—that's being utilized by foreign companies is our technology. I again come back to the feeling that the aircraft industry is similar to the automobile industry 10 years ago. I just don't see a willingness of American companies to go out and meet that market, and I think it's an ever-growing market. It's going to—in my opinion, and I am not an industry analyst by any stretch of the imagination—but in my opinion, that market is going to be a predominant market as opposed to the larger types of aircraft that Boeing, your company, and Douglas have built from—let's say, from the 727's and DC-9's upward, where we've put a lot of emphasis. And we have nobody really putting a great deal of emphasis in the smaller plane.

Maybe I read the industry wrong, but I just, for some reason, think that, like the automobile industry, we decided to continue to build bigger and bigger automobiles until we found out from foreign intervention or from foreign influence in the buying market that indeed the American public was waiting for a different type of mouse trap.

Mr. STEINER. Well, I guess I have great difficulty in likening the aeronautics industry—which is on the threshold of really enormous technological improvements and, in many cases, is seeking valiantly to exploit them both militarily and commercially—likening that to the automotive industry.

And I do not agree with you on your comment that we like to build big airplanes, so we go build them and let somebody else build the smaller ones because they build them better. We can build just as good smaller airplanes as the other guy can.

Mr. CARNEY. Well, why aren't we doing it, that's my question?

Mr. STEINER. I would prefer that one of the later speakers who represents that element of the industry answer that question. But I can tell you that it's solvable; it's technologically oriented; and it's financially oriented. And it's in part financially oriented by the condition of the customer.

Mr. CARNEY. Well, telling me it's solvable and telling me how to solve it are two different things and that's—you know, we would hope that we are having hearings on an issue that indeed is solvable. We are just trying to find some leadership into how to solve the problems.

Mr. **Steiner**. I would be glad to cooperate in any effort to look at the various elements of solving that particular smaller transport problem. And I agree with you that the market is very large.

Mr. **Carney**. Let's go back to the military side again. I asked the question about where you think we should go on the commercial end of it. Is there any particular area we should be trying to advance ourselves in from a military standpoint?

Mr. **Steiner**. Well, I think we should endeavor to advance ourselves in terms of both the low-speed efficiency objective and the high performance, high altitude, very high speed, transatmospheric environment.

I believe that much of the technology is common but in some cases it's not common. I believe we should be having a very wide front in terms of our military objectives. In my printed statement, submitted for the record, there's mention also of other potentials. For instance, if we really wanted a stand-off weapon that was going to be in the air for several days, or even weeks, we might go to an entirely different technology than we would use, say, in the civil or military transport of today.

I would say there's lots of military opportunities there more varied than the civil but they have the same roots.

Mr. **Carney**. Thank you.

My final question, Mr. Steiner, is this: In your testimony you did mention that NASA could use more money? We are presently funding them in this particular area, in the area of about $300.2 million. What would you suggest would be adequate funding for fiscal year 1985?

Mr. **Steiner**. I doubt that as representative of Dr. Keyworth's office I should answer that question with a number, sir.

Mr. **Carney**. I think the punter on the Redskins should be careful. There's another good one in town too. [Laughter.]

I yield back the balance of my time.

Mr. **Glickman**. Thank you, Dr. Steiner, very much, for testifying.

Our next witness is my friend Dr. Hans Mark, Deputy Administrator of NASA, formerly Secretary of the Air Force, and many other things as well. And I understand that the Administrator, Mr. Beggs, was called too by the White House today, and we are particularly appreciative that you are here, Dr. Mark. And you may proceed as you deem appropriate.

STATEMENT OF DR. HANS MARK, DEPUTY ADMINISTRATOR, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION, ON BEHALF OF JAMES M. BEGGS, ADMINISTRATOR, NASA

Dr. **Mark**. Mr. Chairman, and members of the subcommittee, I am pleased to be here. I am representing Mr. Beggs. I have submitted his statement for the record. I have to say I feel a little bit apprehensive about the fast company I find myself in because Chuck Yeager and Jay Keyworth and Jack Steiner are all people who have had great influence in this—in this business.

I would especially like to commend the leadership that Jay Keyworth has shown in heightening the consciousness of the administration toward an active and strong aeronautics research and development program.

I would like to just share a few impressions with you for a few minutes before we get to the questions which I think are really——

Mr. GLICKMAN. Your entire statement will appear in the record.

Dr. MARK. I don't have a statement. I——

Mr. GLICKMAN. Well, the statement of Mr. Beggs.

Dr. MARK. I submitted Mr. Beggs statement. I am just going to say a few things.

And let me start with Jack Steiner's bed of bricks, as he called it. That's really NASA's job—the construction of that base. And let me talk a little bit about what we've done in the last 10 years to enhance and advance the state of our bed of bricks in this business. Through the foresight of the Congress we were able to fund the national aeronautical facilities program back in 1974. And, we are now in the process of putting on line three large new aeronautical facilities—the 40 by 80 wind tunnel extension at Ames, the national transonic facility that is going to be dedicated tomorrow by the Vice President, and the engine test facility at the Arnold Engineering Development Test Center. That was a billion dollar—not quite a billion dollar program, but it's a very, very large investment in new facilities. And I think it's to the credit of all of us who are in the business that we got together at the beginning of the last decade, formulated that program and then went through with it.

A second thing that we've done in the last decade that I believe is very important is that we have constructed and developed the art of building complicated and high fidelity flight simulators. We now have in our inventory flight simulators that permit us to take very significant short cuts in the design process of new airplanes. I am speaking here of the flight simulator for advanced aircraft, the vertical motion simulator, and the differential maneuvering simulators that we have for military airplanes.

Finally, Mr. Chairman, much has been said about the lack of experimental aircraft program—the fact of the matter is that we have conducted an active experimental aircraft program in the last decade. We built the X-15, we built the QSRA, we built another modification of a Buffalo aircraft for STOL investigations;[1] we've done the F-8 program, the fly-by-wire program. There's a series of experimental airplane programs that have been carried out.

I should hasten to add, sir, that they have not been focused on the thing that—that General Yeager and people have talked about—they have not been focused on the higher, faster, farther kind of objective. But, nevertheless, we have carried out an active flight research program in the last 10 years. And I thoroughly agree with Mr. Webb that you can't do anything that has any value in aviation without experimental airplanes.

So much for the past. What are we going to do in the next decade and what I would like to do, if I may, the word vision has been used. I would like to share, if I may, some visions.

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[1] See app. I, footnote 1, p. 143.

Before I do that, I forgot to mention one other thing that is terribly important in Jack Steiner's bed of bricks and that's the human element. We have, in the last year, recognized that we needed to put more people on the aeronautics R&D task, and we've done that. We have shifted approximately 150 positions from areas that have to do with space shuttle development, and things like that, to the aeronautics research and development centers. You saw those numbers when we put our budget before you last year. And I think that we will probably continue a trend in that direction.

So the elements of facilities, people, and the flight research program are there and, of course, will continue to be there. But let me now, if I may, talk a little bit about some visions for the future.

In terms of the bed of bricks, that is, in terms of the facilities and the people, let me mention a couple of things. One is that we are—our highest priority, new research facilities is the numerical aerodynamic simulation. That is a new departure in how we do aeronautical research and development. And those of us who have been involved in that business for a while are very hopeful that with that device we will be able to cut very substantial time off the development period for new airplanes and, furthermore, we will make the designs that we come up with contain lower risk, that is,[2] lower risk of success.

The second facility that's very important that we are just putting on line is an avionics test facility at Langley—it's basically an avionics simulator which will do, I believe, for the all-electric airplane and these concepts that people have been talking about the same thing that the advanced flight simulators that I mentioned before have done for other elements of aircraft design.

In the—finally, in the realm of facilities, we are refurbishing and expanding our ability to do hypersonic research on the ground. And I want to get back to that in a minute when I talk about this question of visions as it's been put.

Let me be very, very specific about some visions now that I would like to share with you between now and the year 2000. First, let me talk about the so-called JVX program, whereas, you know the military has committed to the creation of a 40,000-pound airplane based on the tilt-rotor principle and designed to replace the helicopters that the U.S. Marine Corps now uses in assault-type situations. That is a—an excellent example of how we do business. We built some proof of concept airplanes back in the sixties; we built a really good experimental airplane to validate the concept in the seventies and now [3] we are committing to the production.

I believe, Mr. Chairman, and this is now a vision I have. But once the military builds 1,000 of these airplanes, the commercial sector will take them over and we will not build 1,000, but 10,000 and 20,000, because they will sell. They will, in fact, I believe, do what you asked Mr. Steiner, namely, how are we going to leapfrog the Dash 7's? We are going to do it with the tilt rotors. And we are going to do it with the tilt rotors, sir, because they require fewer ground facilities to operate. They can, in fact, land right in the middle of a city on top of your office buildings, if you want.

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[2] See app. I, footnote 2, p. 143.

[3] See app. I, footnote 3, p. 143.

I think that is going to happen. That is a vision I have. And I think it is going to happen in due course because the sequence of events that I've just talked about is one that we've gone through before.

Our current generation of jet transports are direct technical descendants of military aircraft that were developed after the [4] war—large multiengine jet aircraft. And once the military flew those airplanes around and saw many of the maintenance and economic problems—once the cost figures for operating those airplanes were well-known because of the military operations, the commercial folks would come in and take the risk and go and do it. I think the same thing is going to happen with the tilt-rotor. The question of—and I say that's a leapfrog—that's the kind of thing that nobody has and we will be doing it.

The question of the supersonic transport was mentioned. I also have a vision there. I think there's going to be a supersonic transport and I think it's going to happen sooner rather than later. And let me tell you how I think it's going to happen—it's going to happen roughly in the same sequence that I have just talked about with respect to the tilt-rotor.

We are building the B-1B. The B-1B is the largest variable geometry aircraft we've ever built. You remember that back when we were doing the SST program in the late sixties, there was a competition between Lockheed and Jack Steiner's corporation.[5] Jack Steiner's company won that competition because they proposed a variable geometry airplane.

Mr. GLICKMAN. Would you explain variable geometry airplane?

Dr. MARK. A variable [6] sweep.

Mr. GLICKMAN. OK.

Dr. MARK. OK.

Now, that's terribly important because with that variable sweep airplane you buy noise reduction because you don't have to run your engines full tilt to get off the ground. OK? And that's one important thing. And, two, you can do even a better job flying supersonically than you can with a fixed geometry airplane where you have to compromise in order for it to fly well at low speeds.

Now, why did we—why did Boeing abandon the variable geometry airplane? They abandoned it, sir, because at the same time we were developing the [7]—what is now the F-111, the FB-111, and we had problems with the mechanism for sweeping those wings. And at some point or other, somebody said, hey, that's a risk we can't take. And so we're going to get off it.[8]

Now, here again is an example where we will start flying—100 B-1's for hundreds of thousands of hours. And we will learn how to deal with the problem of how to operate airplanes like that. We will learn what it costs to maintain them. We will learn what it costs to fly them. And once we have those answers, the commercial people will come in and they will build a very much better SST than we have now because of that.

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[4] See app. I, footnote 4, p. 143.

[5] See app. I, footnote 5, p. 143.

[6] See app. I, footnote 6, p. 143.

[7] See app. I, footnote 7, p. 143.

[8] See app. I, footnote 8, p. 143.

They will build an SST that is environmentally much less invasive because it is quieter, it will be—land very much and take off very much like a regular subsonic jet and it will optimize itself, due to the variable geometry for supersonic flight in a much better way than the current SST's. It will have more range—one of the big problems with the current SST's is they don't have enough range. They can barely get across the Atlantic; and, of course, the big advantage of supersonic flight is across the Pacific, not the Atlantic, because that's where there's a big time problem.

Now, so I have those two visions. I think we will have a short-haul system based on the tilt rotor technology. We will have an SST based on what we will learn from flying around B-1's.[9] That's a fallout.

Third—and let me turn to[10] the military now because that's been a—been a question that's been touched upon here occasionally. The most significant fact about our tactical military situation today is that the creation of the airplanes we have has been governed by an interesting political ground rule that has been established in the wars that have been fought since the end of the Second World War.

If you look at all those conflicts, you find, interestingly enough, that in every one, tactical air power has operated from sanctuaries that were never attacked. You look at Korea, you look at Vietnam—we operated aircraft carriers in the Gulf of Tonkin, which were not attacked by our enemies. We operated airplanes out of Thailand from bases that were by tacit agreement sanctuaries.

I don't believe that situation is a constant of the political system. As a matter of fact, I think we are in a somewhat anomalous position because of that. We have not thought very hard about the problem of how you operate military aircraft when your bases are under attack. Incidentally, that same ground rule also applies in the Middle East. The two sides don't attack each other's bases.

Now, I think we are technically in a position now where we can build high performance—not VTOL necessarily, but short takeoff and vertical landing airplane. You see, the vertical landing is the important thing; not the vertical takeoff, because you want to get back to some—the problem is to get back to an airfield that's been attacked and that's where you need the vertical landing.

Last May, we had a meeting with our British friends. They know a lot about vertical airplanes—takeoff and landing airplanes—they have the Harriers. The Harriers were crucial in the Falklands conflict. I don't want to get into that but that was a clear object lesson on why you need airplanes like that.

And we are looking toward, Mr. Chairman, the development of a joint British-U.S. research aircraft for the creation of the next generation of fighter aircraft that will be both supersonic and will have what we call short takeoff and vertical landing capabilities. And for that we will need a research aircraft and we are going to do that. We are now—we are going to have another meeting in a month with the British and we are going to lay out the kind of program that—to achieve that end.

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[9] See app. I, footnote 9, p. 143.

[10] See app. I, footnote 10, p. 143.

Let me get to a fourth and last vision. And this is a vision, again. I should say that in contrast to the tilt rotor and the SST, which I think will occur much before the end of this century, the creation of a high performance short takeoff and vertical landing fighter plane, our best guess—and that's the conclusion we came to last May, was that we we would field one of these things by the year 2000. So that's a longer term vision, if you like.

I have another final vision that I'd like to share with you, which has to do with the—a topic that was touched upon by several people in their—in their statements, and that has to do with the question of hypersonic flight.

I believe we will do hypersonic flight. I—in contrast to somebody who said there is no requirement, I believe that a requirement will emerge very shortly. Last March, the President made a remarkable speech about the possibility of creating a defense against nuclear ballistic missiles. Those defenses, Mr. Chairman, will have to be built on the boundary line between space and the atmosphere. And it is my considered opinion that at some point or other we will require either manned or unmannned vehicles that fly in a sustained way in the upper atmosphere with the kind of ram jet propulsion[11] and in the hypersonic in the mach 7 range and so on that people have talked about. I believe that will happen.

I also believe that the means for creating that technology is at hand. And the means I'm talking about here is the space shuttle.

People have talked about the X-15, they have talked about the X-1, they have talked about the very remarkable research program that was done in the late fifties and the sixties. What hasn't been said yet is that every one of those research airplanes, Mr. Chairman, was dropped either from a B-52 or a B-29. The state of technology at that time was not there, where those airplanes could take off from the ground and do a research job. The shuttle, Mr. Chairman, gives us the ability to drop hypersonic research airplanes precisely the same way that we dropped the X-15 and the airplanes that we built in the sixties. And we are in the process of developing a proposal for a program to do precisely that, namely, to build research aircraft that fit in the shuttle bay, that will then be dropped, and it will fly in one way or another in the upper atmosphere and we will learn what flight in that regime is all about.

That also is a vision I have, a vision which is a longer term one than the others that I have tried to lay out before you. But I think we're going to do that, and I think we're going to do that because those vehicles are going to be vitally important in the direction ultimately of the defensive systems against nuclear ballistic missiles that the President spoke of last March.

I think I might as well quit now and do some questions and answers. Time is running out. So thank you very much, Mr. Chairman.

[The prepared statement of Mr. Beggs follows:]

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[11] See app. I, footnote 11, p. 143.

Statement of

Mr. James M. Beggs
Administrator

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

before the

Subcommittee on Transportation, Aviation and Materials
Committee on Science and Technology
House of Representatives

Mr. Chairman and Members of the Subcommittee:

For the greater part of the 20th Century, NASA and its predecessor the National Advisory Committee on Aeronautics (NACA) have concentrated on the development of technology for superior U.S. aircraft. It is fitting at this time that we consider the challenges and the opportunities of the 21st Century, and I am pleased that this Subcommittee -- which has played an important part in the planning and support of our past and present programs -- is devoting this hearing to that purpose.

In announcing the completion of the Office of Science and Technology Policy (OSTP) Aeronautics study last year Dr. Keyworth declared as a National policy objective the "provision of a proven technology base to support the future development of superior U.S. aircraft." The study reaffirmed NASA's role in this important government process, and we are committed to implementing the policy and maintaining to the best of our ability a balanced and forward looking program of aeronautical research and technology development.

One of the questions dealt with in the OSTP Policy Study concerned the potential for further technical advances in aeronautics. The study found that "large gains are expected from continued aeronautical R&T" and I strongly concur in that finding.

We have seen phenomenal advances in the capability and reliability of aircraft in the relatively short time between the Wright Flyer and the Space Shuttle. We have developed in this country an unrivaled public air transportation system, and a fleet of private aircraft providing personal air transportation that is without equal in the world; and we have maintained a clear preeminence in military air capability. NASA is proud to have played a major role in providing the technological foundation for many of these accomplishments.

Aeronautics, I believe, still offers the potential for significant advances in each of the aeronautical disciplines -- aerodynamics, structures and materials, propulsion, and controls -- and, perhaps even more importantly, in the ability to combine these individual advances into integrated technology for totally new aircraft systems. In addition, continued progress in related areas such as electronics, computer sciences, artificial intelligence, fiber optics, laser technology, and quite probably some fields we cannot even identify at present, will even further increase the potential for progress in aeronautics over the next century.

To maintain our frame of reference as the period beyond the year 2000, I propose to touch only briefly on the future of conventional subsonic transports, general aviation, and helicopters as we know them today. Subsonic transports are presently the backbone of our civil aviation system and the technology embodied in them is, in many instances, equally applicable to military aircraft. They will remain important to us for many years and aeronautical research will continue to be devoted to developing the technology for necessary improvements in their safety, productivity, and operational effectiveness. Technology based on research currently in progress -- for example, lightweight composite structures, viscous drag reduction, more efficient turbofan and propfan propulsion, and active controls -- could be used in transport configurations near the turn of the century to produce as much as a three fold increase in seat-miles per gallon. Subsequent developments in the 21st Century might well produce very large subsonic long-range cargo aircraft to serve growing future needs in both civil transport and military airlift, offering twice the range/payload of the C-5B with less than a one third increase in gross weight and with a doubling of fuel efficiency.

Substantial gains can also be foreseen in the levels of technology applied to general aviation, particularly as related to efficiency, safety, and automation of pilot tasks. As to conventional helicopters, advances in noise and vibration reduction, all-weather capability, and productivity will greatly expand their use in civil transportation as well as in the special-purpose, utility, and military missions performed by helicopters today.

For our discussion of aeronautics in the future, however, I would like to focus our attention on several areas which I believe represent significant new opportunities and challenges for the year 2000 and beyond. These are supersonic cruise, high-speed rotorcraft, short-haul subsonic transportation, and hypersonic flight.

Supersonic Cruise

Advances in supersonic cruise technology will provide options for both civil transportation and military aircraft. Concorde has already proven the technical feasibility of supersonic air transportation. It has also proven that a system based on technology of the 1960's cannot be economically viable. Nevertheless, and despite recent setbacks and current uncertainties in the air transport business, I believe that the next century will be characterized by several trends which are almost certain to improve the outlook for long-range transportation. World population is still growing and will continue to grow during the next century. The largest component of this growth -- over 75 percent -- will be in the developing nations. The growth of population and industry in the Pacific Basin, South America, Asia, and Africa -- and the resulting increase in trade and multinational business - will create a market for over-ocean transportation at stage lengths considerably greater than north Atlantic ranges. The long ranges, and the large percentage of travel which will be business, rather than tourist, oriented, will increase the value of reduced trip time and increased productivity, and will precipitate a renewed interest in supersonic transportation. Design studies conducted by the major aircraft manufacturers indicate that an advanced technology supersonic transport could carry 300 to 400 passengers over intercontinental ranges, at more than three times the speed -- and the productivity -- of today's subsonic transports. Operating cost estimates suggest that fares may be affordable and some configuration approaches appear to maintain sufficiently low sonic boom overpressures so that flight over land may be practical.

The Supersonic Transport (SST) of the future would incorporate highly efficient aerodynamic configurations, laminar flow control made feasible by new surface materials, advanced high-temperature structural design, and variable cycle engines. The variable cycle engine technology, when developed, will offer a 40 percent increase in supersonic cruise efficiency combined with low noise on takeoff and efficient subsonic operation.

In my opinion, the supersonic-cruise technology has important application to future combat aircraft as well as to transports. Current fighters typically posses only limited-duration supersonic dash capability because of their high fuel consumption at supersonic speeds. Recent studies and combat experience indicate that sustained supersonic cruise, coupled with high maneuver capability, would result in considerable increase in combat effectiveness and survivability. The higher thrust-to-weight ratios associated with supersonic cruise technology also increase the feasibility of short takeoff and vertical landing (STOVL) capability for potential future fighters. Supersonic STOVL capability based on augmentor/ejector or other propulsive-lift technology approaches now being investigated could permit efficient supersonic cruise as well as practical vertical landing with low-velocity, low-temperature efflux footprints.

High-Speed Rotorcraft

Although an order of magnitude slower than supersonic aircraft, new forms of rotary-wing vehicles will be capable of much higher speeds than present-day helicopters, enabling them to assume a much broader role in both civil and military operations. Tilt-rotor technology, developed in joint NASA/Army research and presently being considered for application in the Navy's JVX program, now makes it possible for a vehicle to retain the vertical flight and hover advantages of the helicopter, while capable of efficient, smooth, quiet forward flight at speeds approaching those of current propeller-driven airplanes. This capability represents a first but important step toward entirely new generations of high-speed rotary-wing aircraft which will be able to serve a variety of military and civil applications. The increased speed, range, economy, payload, and comfort advantages may provide a basis for large-scale inter-city and inter-region civil transportation. Also, the combined vertical/forward speed benefits may be important in filling need brought about by conditions as disparate as urban congestion in highly developed areas and primitive terrain in developing areas. Another possible focus for a future helicopter may be on large rotorcraft technology.

The projected advances in rotorcraft technology will stem from continued progress in aero-structural dynamics, reduction of noise and vibration, all-weather guidance and navigation, advanced controls and control integration, and advanced structures. In addition, future rotorcraft may benefit considerably from advances in the area of small turbine engines. Recent research has shown that new high-temperature materials and advanced component technology can be developed to permit major improvements in the fuel consumption and the thrust-to-weight ratios of small engines, which are currently much less efficient than the larger engines because of the cooling, clearance, and other difficulties associated with the small size. The advances in small turbine engine technology may have applications in general aviation and cruise missiles as well as in rotorcraft.

Short-Haul Transports

As suggested earlier, in my opinion, much of the future long-range air travel may be provided by supersonic transports. A large percentage of air transportation in this country, however, and even more so in Europe and elsewhere, consists of trips at stage lengths from 100 to 500 miles. Some of these short-haul needs are being filled today by low-cost small commuter aircraft many of foreign manufacture. As the population grows and continues to shift away from the older metropolitan areas, and as new urban areas and industrial centers develop in the next century, the necessity for efficient, comfortable short-haul air transportation will increase rapidly. Similar needs in other countries will create important world markets for such transports. The small commuters will largely be replaced by aircraft with capacities of 50 to 100 passengers or more, designed to large-transport standards of airworthiness, operation, safety, and dependability but designed also for maximum efficiency during climb, descent, and short-stage-length flight. They will also be able to operate safely and quietly at relatively small airports or on short runways at hub terminals.

Advanced turboprop technology may be an important contributor to this future generation of vehicles, by providing important improvements in fuel economy. Although potentially useful in many applications, the advanced turboprop may be of special benefit in the short-haul transports of the future, providing additional economy at the shorter distances. The new short-haul transports may also utilize the advances resulting from ongoing research now being directed at long haul transports in areas such as drag reduction, lightweight structure, active controls technology, and safety. They may also utilize propulsive lift for the short-runway capability.

Hypersonic Flight

The last area I wish to cite is that of hypersonic flight. The X-15 research airplane permitted some exploration of the hypersonic regime in the early 1960's and, in fact, helped set the stage for the Shuttle and other space vehicles which must pass through the hypersonic regime on the way to and from orbit.

The maintenance of sustained hypersonic flight for much longer periods is a different matter, presenting more difficult technical problems in propulsion and aerodynamic heating. Research has indicated that these problems may be solvable, however, and I believe hypersonic flight operations in the next century could be made practical and perhaps even routine. Long-range cruise missiles utilizing supersonic-combustion ramjets (scramjets) and high-density hydrocarbon fuels may be the first generation of operational hypersonic vehicles, followed later by very-high-altitude Mach 5-7 cruise airplanes used for strategic reconnaissance. There is also renewed interest in a hypersonic maneuvering airplane capable of sustained operation both in the atmosphere and in low orbit. It would utilize a combination of scramjet and rocket propulsion to match the transatmospheric envelope, and would probably have horizontal takeoff as well as landing capability.

NASA has been engaged in research on scramjet propulsion for many years with encouraging progress. The difficulty has been that, for efficient hypersonic propulsion, the scramjet cannot be viewed as an engine isolated from the vehicle. Rather, the high-temperature structure of the vehicle itself must be used as the engine inlet and portions of the structure must be moved by an automated control system to provide the necessary inlet and nozzle adjustments. Thus, use of this technology will involve a highly coordinated systems-research effort in the propulsion. aerodynamic, structure, and control disciplines.

Facing the Future

I have identified several of the major areas of new aeronautical development expected in the future. Ongoing research and technology efforts which are the primary source of the seeds for long-range future growth, may well lead to additional and perhaps even more important next-century developments which cannot yet be identified. Whether directed at specific potential aircraft or not, aeronautical research and technology involve very long lead times, and it is appropriate to consider our ability to meet the anticipated needs and opportunities of the year 2000 and beyond.

Two areas of extreme importance to aeronautical developments in all vehicle types in the future are the growing dependence on numerical aerodynamic simulation in aircraft and engine design and the use of microelectronics in aircraft controls. We have recognized the need for increased emphasis in both areas and are taking effective action to provide it.

Computational fluid dynamics is essential for enhancing the understanding of aeronautical phenomena and for facilitating the aeronautical design process. Although currently limited by computational speed, the numerical aerodynamic simulation goal of a "digital wind tunnel" will be reached before the end of the decade, providing the capability to analyze the three-dimensional flow around an airplane and through the rotating turbomachinery of an engine. This ability to model the flow field around complex geometries is crucial to the design of highly integrated airframe and propulsion configurations of the future. The next step, solutions to the full Navier-Stokes equations, will provide exact solutions for the real flow of gases that will allow accurate modeling of turbulence and separated flow, opening the way to a broad range of control mechanisms for favorably altering aerodynamic flows.

With the introduction of new microelectronics and computer technologies, opportunities to achieve higher levels of system integration and automation will allow aircraft of the future to fully exploit advances in aerodynamics, propulsion, structures, and cockpit systems. The Space Shuttle, with greater computing power than any vehicle ever flown, is today the best example of a highly integrated aerospace vehicle, and provides a valuable experience base for aircraft systems of the future. The technology advances to be incorporated in the aircraft of the next century, however, will require an even greater systems integration capability. Highly reliable flight-crucial controls, electric power systems, and electromechanical actuators allow replacement of mechanical, hydraulic, and pneumatic systems with all electric systems having higher reliability and lower weight. Fly-by-light using fiber optics may offer still greater flexibility, reduced weight, and protection from lightning effects. Active control technology for load alleviation and flutter suppression may be used to significantly improve the ride quality, reduce pilot workload, and reduce structural fatigue.

Many of the tools and facilities that will be required to support research, technology and vehicle development into the 21st Century either already exit or are under development. The aeronautical R&D process requires a full spectrum of ground based facilities and flight research test beds. Our advanced simulators are capable of duplicating many flight situations with a high degree of fidelity and are steadily improving with advances in high-speed computers. The Numerical Aerodynamic Simulation program will provide the United States with the world's most advanced computational capability and will also be able to take advantage of future advances in high-speed numerical processors. In both the low-speed and high-speed wind tunnel areas, we have an impressive capability which has been augmented by the National Transonic Facility which will be dedicated at Langley Research Center on December 6, and will be further enhanced when the 40x80x120-foot wind tunnel at Ames Research Center is operational. As we look further toward the future, we may need to consider additional hypersonic engine testing capability as well as improved capability for integrated airframe/propulsion systems research in which altitude, temperature, and speed effects may be studied concurrently.

In addition to these ground-based facilities, flight research continues to be an important element of technology development. In many instances, the flight research test can be obtained economically by modification of an existing aircraft. The AFTI-16 and AFTI-111 (Mission Adaptive Wing) programs are being accomplished in this manner. A similar test-bed approach could be adopted for research on a variety of advanced aeronautical concepts.

The unique nature of the flight environment or the unique technology integration requirements of the concept itself may eventually demand essentially all new experimental aircraft. Recent very successful examples of current NASA experimental aircraft activity include the tilt-rotor XV-15 and the propulsive-lift QSRA. Similar activity is now being undertaken with DARPA's X-29 and X-Wing research aircraft. Some of these programs have been NASA-funded, some have been jointly funded with DOD, and some have been DOD programs with NASA assistance. It is my view that this approach should be continued into the future, with sponsorship decided on each program according to its content. In the hypersonic and supersonic STOVL areas for example, I believe the research vehicles should be funded principally DOD, since the primary driver for applications will be military in the foreseeable future and the programs will involve very large expenditures.

The future of aeronautics in the next century is replete with technology opportunities for growth and advancement even more impressive and exciting then those we have witnessed in the present century. Successful realization of these opportunities will require continued effort and commitment by all involved sectors. NASA's ongoing research is providing a solid foundation from which we can proceed effectively in those directions selected on the basis of national needs and priorities. Thank you, Mr. Chairman and I would be pleased to answer any questions you may have.

Mr. GLICKMAN. It was a very good statement, and Mr. Carney and I—well, Mr. Carney leaned over to me and said you were the "Martin Luther King of aeronautics." You know, you have a lot of dreams here.

I guess my first question to you is, is the level—do you want to respond?

Dr. MARK. I am flattered by the comparison, sir.

Mr. GLICKMAN. Well, you know——

Dr. MARK. I really am.

Mr. GLICKMAN. You should be. But is the level of the NASA aeronautical budget, or commitment, adequate to achieve any kind of these four technical advances? Of course, you have gone through the tilt rotor essentially right now, and now we're in the process to see what happens internally with the military and whether they decide to pick it up or not. But, I mean, are you talking about anything that's feasible and realistic in terms of NASA's role in these projects, or are you talking about something that's going to be all done by the Defense Department?

Dr. MARK. No, sir. I'm talking about something that will be done jointly between NASA and the Defense Department, precisely the way we did the tilt rotor, jointly between NASA and the Department. You remember the Army paid for half of it and we paid for the other half.

I think the resources we have are, to use your word, adequate. Adequate, to me, means they are always too small. I would very much like to have more. But the fact of the matter is that we do have a resource problem, and for the things that I've talked about the resources are there. We have put them there. We have put the resources there, as you will see eventually, to create the ground facilities, to lay the bed of bricks for the hypersonic stuff. We have put the resources there for the short takeoff[12] and landing and verticial—short takeoff and vertical landing fighter technology. We are talking to our friends, the British, right now. We are laying out a joint research program with them.

That isn't easy, by the way, because our people say why do we want to do that; we know better than anybody else and the British are worried about "gee whiz, are they going to steal the Harrier from us." I mean, it is not an easy thing to do, but we're going to do it and we're going to do it because the British know a little bit more about this business than we do and we must learn from them.

Mr. GLICKMAN. OK. And I want to make sure, as you said, that it's done not only to pursue the military side of the picture, but also the commercial side of the picture. That's very, very important in terms of the expenditure of public dollars.

Dr. MARK. Yes, sir, I agree. And you—go ahead.

Mr. GLICKMAN. Go ahead. I'll let you finish what you were——

Dr. MARK. Well, I think the commercial side, the importance in the commercial side—and let me—I forgot to mention that, and let me talk a little bit about it.

You know, we fly the Dash 7's into National Airport right now, and you've all flown on them. That is something, incidentally, that a technology or occurrence that we foresaw back in 1969. You may remember, Mr. Chairman, at a hearing before your committee about a year ago, I think, I brought a large book that we put out in 1969 where we said that the short-haul technology will be something that will happen because more and more regions of the country that have not got access to the large airplanes will want it. And so we didn't foresee the exact circumstances and we didn't foresee the gasoline price rises and the deregulation and all these things, but it's happening. Those people are using flight procedures that we developed with our STOL experimental airplanes at Ames 10 years ago. They're using avionics; they're using the things that we worked on.

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[12] See app. I, footnote 12, p. 143.

I am confident that when the tilt rotor takes over that market, as I think it will, the flight procedures that we're working on now for the tilt rotor will also be the ones that the commercial folks will want to take over. So we always keep our eye on the ultimate commercial application of these technologies. It's very important.

Mr. GLICKMAN. Well, just echoing a personal experience, I recall when President Carter came in and he asked to cancel the B-1, and I supported him the first time, but after a period of time I came to realize two things: One is if the Stealth is ever built, it may be built in time for my grandchildren—maybe; and second of all, that the enormous spinoffs that could develop to commercial transportation would not occur if that airplane were not built. So let me go to the SST-related question.

You say that the B-1 will produce enough interest, research data, that we will go ahead and produce an acceptable supersonic transport maybe by the year 2000; is that correct?

Dr. MARK. Yes. I believe it will happen before the year 2000. What the B-1 will do is create the confidence. It will create the confidence among the airline operators, that airplanes of that kind can be operated at a well-known cost.

You see, the problem an airline faces when it buys an airplane is it has got to know very accurately what that airplane costs to operate. That's what Mr. Steiner and his colleagues at Boeing have done so well. They have really narrowed down the uncertainty that an airline faces, the risk that an airline faces when it buys one of their airplanes. That's why they're so popular.

The problem with the SST right now is that nobody knows those costs, really. We know it for the Concorde and we know they don't work.[13]

Now, suppose you could build an SST that can fly subsonically, get into a lot of airports, doesn't make much noise over a community, but then can go at Mach 2 over long distances. You know, that's an interesting proposition for airline operators, except right now none of them know how much it costs. None of us know how much it costs. The B-1 will tell us, and from there on that will be a data point, and from there on we can do parametric analyses that will be a hell of a lot better than what we know now.

Mr. GLICKMAN. Are you saying the B-1 then is the research airplane for the——

Dr. MARK. Well, it is not a tech—certainly it's an economic research airplane. It's not a technical research airplane, because the technology is there. The problem is to understand the precise cost of running it.

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[13] See app. I, footnote 13, p. 143.

You see, look. When we started to fly B-47's and B-52's in the late 1940's, nobody knew what the maintenance cost of a jet engine was. There was no way that you could get commercial operators to go into jet propelled airplanes because—and we didn't know that for 10 years. You know, it took 10 years of flying those airplanes around, ironing out the bugs. We used to throw engine blades and we used to do, you know, things of that kind. Once those bugs were ironed out, once the costs were nailed down, it didn't take very long for the commercial operators to take over.

Mr. GLICKMAN. Well, let me ask you this, then. Let's go back to the role of NASA and research airplanes. You talked about the fact that we have had a continuing scenario of research airplanes even past the X-15. But let's——

Dr. MARK. But they were in a different field.

Mr. GLICKMAN. A different field, right. OK. But let's assume that we're going back to the faster, higher airplanes. What would be your judgment on regenerating a modern-day research airplane with the newer envelope, the faster, higher envelope——

Dr. MARK. Well, we're going to drop them from the shuttle. You see, the higher, faster, further regime I believe will be these aerospace airplanes that we're talking about, and we are working on the development of a flight test program using the shuttle exactly the way we used the B-52's and——

Mr. GLICKMAN. Are you going to have that in your fiscal 1985 budget request to us?

Dr. MARK. We will have—well, certainly in our [14] base there will be an item studying precisely what I have just said. We are not yet ready to turn that into a line item and spend a lot of money on it. We are right now asking ourselves the questions: "How would we go about doing this and what could we learn?" "What would be the total cost?" Yes, sir, you bet we're going to do that.

Mr. GLICKMAN. OK. So to just summarize again, to pursue that higher, faster, further envelope, you're looking at a combination of usage of the shuttle along with basically using an airplane to——

Dr. MARK. Yes——

Mr. GLICKMAN [continuing]. Pursue that technology, and some recommendation will be forthcoming——

Dr. MARK. We are, yes——

Mr. GLICKMAN [continuing]. To fund such a research airplane?

Dr. MARK. Yes. You know, not this year, but we very definitely will want to look at airplanes that fly in the upper atmosphere, either manned or unmanned, depending on the mission, and for the reason that I have speculated on.

Mr. GLICKMAN. Let me just go back to the SST for a minute. Do you think your research on supersonic cruise to date has shown progress in resolving economic and environmental problems of the original SST, or again, will this be validated by the B-1B award?

Dr. MARK. Yeah. Mr. Chairman, I believe had we stuck with the swept-wing airplane, the variable geometry swept airplane, many of the environmental problems that the Concorde created in terms of noise wouldn't be there. You see, the Concorde literally has to stand on its tail to get off the ground. That's where the noise problem comes from.

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[14] See app. I, footnote 14, p. 143.

Now, if you've got an airplane that can fly efficiently at low speeds, you don't have to rev the engines up all the way. I think we knew that back [15] when we—you know, that wasn't a research question. I think the problem on the SST, and I think Jack Steiner said it, is one of economics and not technology. I think we have the technology in hand. We committed to the B-1. That is essentially the technology. And now what the B-1 will teach us is the economics.

Mr. GLICKMAN. Mr. Carney, why don't you go ahead.

Mr. CARNEY. Thank you, Mr. Chairman.

I would like to first thank you for giving us some insight as to what problems are ongoing at NASA and how they eventually will be applied to the area of general aviation. I think that makes one more optimistic, to see that we are moving forward at both ends of the spectrum, the faster and higher, the more accommodating vertical takeoff and landing types of aircraft that I think we're going to need. That leaves me somewhat more optimistic.

But getting back to the operation of your shop, and getting away from some of the technological advances, we recognize that the cost of maintaining NASA's aeronautical facilities is taking a more and more—you might want to say a larger bite out of the R&D budget. Are we moving toward a situation where NASA will be able to provide a superior research facility but have no discretionary R&D funds left over to conduct research?

Dr. MARK. Well, Mr. Carney, we recognized that problem when we—when Mr. Beggs and I came in. And what we did was to enhance—and you approved it here on this committee—enhance the construction of facilities budget, not the R&D budget, the construction of facilities budget, to provide for the upgrading and maintenance of our existing facilities. That's an add on. That's not a—there is not a zero sum game there between research and facilities. Both the administration and the Congress went along with that.

We will again come—I can't tell you the number right now, because we have to wait until January 20—but we will again come with a substantially enhanced construction and maintenance program in that budget which is independent of the R&D.

Mr. CARNEY. I know that we had——

Dr. MARK. Incidentally, may I make one more point?

Mr. CARNEY. Sure.

Dr. MARK. You know, it is always said NASA has a $300 million or so aeronautics program. We actually spend much more on aeronautics. Much of our facilities budget goes to aeronautics. I would estimate there is another [16] 80 or so million a year that goes into aeronautical facilities from our facilities budget. The most important point is that we have [17] 6,000 people working in aeronautics in NASA and the salaries of those people are never counted in the aeronautics program.

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[15] See app. I, footnote 15, p. 143.

[16] See app. I, footnote 16, p. 143.

[17] See app. I, footnote 17, p. 143.

Now,[18] 6,000 people costs us something of the order of $500 million. When you add all that up—well, a little less, let's say $300 million—when you add all that up you get something close to $700 or $800 million in the aeronautics program every year invested by NASA. That's a healthy investment. That's not a small amount of money.

Mr. CARNEY. Well, now you're getting into the micromanagement of it. But isn't it not true that the wind tunnel comes out of R&D, the operation of the wind tunnel comes out of the R&D budget?

Dr. MARK. The operation does, not the construction and maintenance.

Mr. CARNEY. Isn't it true that the computer time and costs come out of R&D budgets?

Dr. MARK. Again, the operation does, not the construction and maintenance. We put the construction funds in a separate line item, called construction of facilities, and about half of that is for upgrading and maintenance chores.

Mr. CARNEY. So then from what you're saying, Dr. Mark, I can rest assured that we're not running into that problem?

Dr. MARK. Sir?

Mr. CARNEY. We're not running into the problem where we are getting premier research facilities at the cost of the dollars that would be used for the research and development itself.

Dr. MARK. I wouldn't go so far as to say that, but we're running into——

Mr. CARNEY. I'm trying to give you an opportunity to say we need more money. I mean——

Dr. MARK. Well, we have a different—we are running into a problem which is quite close to what you have talked about, but for a somewhat different reason. It is not the construction and maintenance that's causing the problem. The problem is that over the years we have cut back our manpower. You know, you've got to remember that NASA, between 1970 and 1980, lost over 10,000 people. We had 32,000, 33,000 employees in 1970, and we have 22,000 today. Of course, some of those cutbacks came out of the aeronautics. So the situation we have in our facilities, sir, is not that we have spent a lot of money on good facilities and no people to run them. We have the people to run them. We don't quite have the people to do the right research programs. So it's really a second-order effect.

One reason we took those 150 slots and moved them from space flight to aeronautics is to enhance the, not only the operational people that we have on the facilities—and they have to be run because our customers, you know, require us to do it—but also those people that do research with them.

Mr. CARNEY. That was the area I was trying to get to, and I appreciate your giving us some insight there.

Have you had an opportunity to read the statement of the Administrator?

Dr. MARK. Yes, sir.

Mr. GLICKMAN. He probably wrote it.

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[18] See app. I, footnote 18, p. 143.

Mr. **Carney**. I have someone whispering in my ear on my immediate right "he probably wrote it."

Dr. **Mark**. I tried to write it, but I didn't succeed this time.

Mr. **Carney**. He pointed out the importance of systems integration if we are to fully realize the benefit of technology advances that have been made.

Do you believe that the present organizational structure which focuses on individual disciplines and vehicle classes effectively addresses this important new field?

Dr. **Mark**. First of all, I don't think systems integration is a new field. It's the kind of thing traditionally NASA has been less concerned with, because the integration of the final system is really something that the industry does.

I guess I'm a little bit concerned about the fact that people seem to get up and say it's a new discovery that we've got to do systems integration. I mean, any engineering system always has to have at some point or other an integration and that job is done.

I think it impacts the research role of NASA in things like, for instance, the integration between the propulsion and the airframe in VTOL vehicles. There it is sort of a first order effect.

I also object, by the way, to calling it an intellectual discipline. It is not. It's terribly, terribly important, but it is not the same as an intellectual discipline such as fluid mechanics, where, you know, in the words of the academic philosopher you can learn more and more about less and less.

Systems integration tends to be the opposite kind of thing, where you must have a broader look at it, and it, therefore, tends not to be done as well in the academic and the research environments. It tends to be done better in the industrial environment where the economic pressures and the other considerations force it.

Mr. **Carney**. Let me ask you this. Obviously, Mr. Beggs sees the importance of that. Are you looking at any organizational changes?

Dr. **Mark**. Not for that purpose; no. We're looking at some organizational changes, but that's not a[19] driver.

Mr. **Carney**. But not for—to enhance systems integration?

Dr. **Mark**. No.

Mr. **Carney**. Thank you. And, again, I thank you for presenting to us some of the programs that are now ongoing.

I yield back the balance of my time.

Mr. **Glickman**. Thank you.

Dr. Mark, how are we going to get the Office of Management and Budget to subscribe to the Hans Mark idea for the future of the aeronautics program?

Dr. **Mark**. Oh, I think by and by, they'll subscribe. You argue with them and you fight battles and you win some and you lose some. I think actually, Mr. Chairman, we've done pretty well.

I think that the—the fact that the aeronautics program, in a generally declining civilian budget, you know, is not only—not only maintaining its level, but I—I believe going to be increased somewhat. I think that's a good system.

Mr. **Glickman**. But that's largely due, isn't it, to the Pentagon's influence and the military side of the picture, which I accept, and

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[19] See app. I, footnote 19, p. 143.

I'm not rejecting, but that is, that OMB has been willing to go along reluctantly because Weinberger and crew have pushed the aeronautics side, haven't they?

Dr. **Mark**. Well, they've done that, but I would—I would really put more emphasis on George Keyworth's role here. I think he's been extremely effective in—in carrying our case with the people in OMB.

Mr. **Glickman**. Well, you know, there—we've got a lot of projects coming up, the whole area of experimental vehicles, the propfan project, which is one that's generated some controversy, I think are all going to be continuing targets by the Office of Management and Budget and I would just hope that your vision, as well as Dr. Keyworth's continues.

Let me ask you this question. You talk about this new research airplane being dropped out of a shuttle. Is this a research airplane that the emphasis on the military side will be in the President's space warfare—we're talking about a research airplane that will conform to the space warfare-related technologies?

Dr. **Mark**. I am speculating. This is a personal speculation that once we really take a hard look at what must be done in order to really build such a system, then it will turn out to be useful to have vehicles, either manned or unmanned, that can fly in the mach 7 to 20 range in the upper atmosphere. OK, that's a speculation.

Ultimately, when we start doing that thing, that will be one of the reasons in the back of our minds, but I want to hasten to add, Mr. Chairman, that we are not at the stage in the hypersonic area where there are any missions that one can hang a program on. We are at a—in a research phase. I thoroughly agree with General Yeager there when you asked him the question whether there were missions for hypersonic vehicles, the answer right now is no. I am speculating that there will be and that they will be related to this problem of strategic defense because they will fly in precisely the region of the atmosphere where that conflict will go on.

Therefore, it seems to me a reasonable speculation that vehicles of that kind will turn out to be useful. Nobody has said that yet in a requirements document and I don't think they'll say it for another 3 or 4 years, but precisely because we're talking about research, it is our job to anticipate some of these things——

Mr. **Glickman**. Well, that, I think——

Dr. **Mark** [continuing]. And see what happens.

Mr. **Glickman** [continuing]. Points up the fact, again, that we're rapidly getting to a point where there is no dividing line between air and space, so to speak. I mean, we're talking about one big subject matter——

Dr. **Mark**. Yes, sir.

Mr. **Glickman** [continuing]. Here.

Mr. **Mark**. That's right.

Mr. **Glickman**. Well, I'd like to thank you for excellent testimony. I'd like to reemphasize the committee's concerns that—and I'll emphasize that to the gentleman from DARPA who's going to be testifying after you, that while it is true that many of the civilian technologies have occurred primarily because of military technologies, we don't want to lose sight of the preeminence of the civilian sector——

Dr. MARK. Oh, yes——

Mr. GLICKMAN [continuing]. Because that's where the jobs are; that's where the long-term benefit to the economy is.

Dr. MARK. Couldn't agree more, sir. Thank you.

Mr. GLICKMAN. Thank you, Dr. Mark.

Our next witness is Dr. Robert S. Cooper, Director of DARPA, the Defense Advance Research Projects Agency. Appreciate your sitting here for 2½ hours, but that does not demean the significance of your testimony.

Dr. COOPER. It's my pleasure, Mr. Chairman. As a matter of fact, I would go almost anywhere to listen to Hans Mark talk. As a matter of fact, I wouldn't have characterized him as the Martin Luther King of aeronautics; it would be more the Wernher von Braun of aeronautics.

Mr. GLICKMAN. Why don't you—you may proceed as you wish. I know you have a prepared statement and you may read it or you may summarize it, as you deem appropriate.

STATEMENT OF DR. ROBERT S. COOPER, DIRECTOR, DEFENSE ADVANCED RESEARCH PROJECTS AGENCY, U.S. DEPARTMENT OF DEFENSE

Dr. COOPER. Mr. Chairman, I'd like to submit my statement for the record, but just briefly, if I might, I'd like to comment on a few of the key issues that are brought out in that statement prior to answering any questions you might have.

First of all, it's important to understand that this is a technological society in which we're a part. The decisions that the U.S. Government and the industry make that are broad in scope and that affect the directions that our technical society will take, are very important issues and so I'm delighted that you are taking up this particular issue of the long-range research in aeronautics because I think it's a key issue, both for defense and for our commercial viability as a nation.

I point out to you that aircraft and aeronautics are going to continue to be a vital part of our defense structure into the 21st century. Roughly one-third of the Department of Defense budget is now devoted to acquisition, operation, and support of aircraft. Now, that's one-third of what is becoming a $300 billion enterprise, and so we're talking about—for defense alone, an enterprise of $100 billion per year. Anything that we can do which is revolutionary and gives us extraordinary new capability in that area is going to affect a large segment of U.S society.

As has been pointed out here a number of times, starting with Chuck Yeager, there are substantial benefits yet to be gained from aeronautics for military use and for commercial use. As a matter of fact, Dr. Keyworth characterized our situation now as being at the dawn of a new renaissance of aeronautics. That may be a little bit too strong of a statement, but I believe that there are a multitude of opportunities to leap forward into new regimes of flight that will benefit our society across the board, including militarily.

Clearly, for the Department of Defense, the main issue, and I suspect the main issues that you will focus your attention on in your questioning, deal with the opportunities in relationship to the military needs, and typically the military pays particular importance to need. As a matter of fact, we have, I believe, a great deal of myopia with regard to our long-term needs in research because of the fact that the imperatives of today are so important to us. That is, the threat from our adversaries is here today and certainly we must meet that threat and much of our resource is devoted to that.

But we have studied from time to time where the technologies of the future could carry us, and I have given to you in my testimony 17 technological areas where we believe there is great promise for the future of military applications. Uppermost in those areas, I'd like to mention two, if I might, which are closely linked together.

As you know, the projects that we've undertaken in the last 7 or 8 years to reduce the observables of military aircraft are now coming to fruition in our systems, and those technologies ranging from the reduction of radar, infrared, acoustic, visual, and other observables of aircraft, hold well to provide a revolution, an order-of-magnitude leap forward in capability.

Now those initial attempts to build aircraft that had low observables were very high risk, but the recognition was there that they would be very high payoff if we could achieve them.

To a large extent, our ability to achieve low-observable aircraft has been based on the technology that was developed in the 1960's and 1970's, the understanding of aeronautics and structures, and to a large extent, that technology grew out of the basic research at NASA and in the Defense Department.

Key in that was our ability to predict using numerical methods, the fluid dynamics of very extraordinary and unusual structures that are related to these low-observable aircraft. Our ability to further progress in this area depends on numerical fluid dynamics and our ability to optimize structures in that area, as well as the use of the facilities which we have just spent about a decade upgrading and integrated flight demonstrations of the technologies that go into these kinds of aircraft.

We have broad programs in the country supported by the Government for research and technology. In defense, in many instances we're conducting or actively planning full-scale technology demonstrations, which I believe are quite important. These demonstrations run the gamut from vertical takeoff and landing aircraft through aircraft of radical new designs such as the X-29 aircraft that you see a model of on the table over there, and including such radical new ideas as the full electronic integration of all of the systems of the aircraft, including the structures and the propulsion.

These demonstrations are going to be increasingly important in the future to capitalize on the basic research that is coming out of our research institutions in aeronautics.

The Federal Government does have a major role to play in aeronautics research and development, both for military and civil aviation purposes. We must work closely with our friends in industry to realize the research potentials that we see coming out of our basic research programs over the next decade.

To that end, the administration's aeronautics policy has been upgraded in the past year and to a large extent now, our programs are beginning to reflect changes in that policy which have grown out of the study of last year. I think that the current Government research and technology plans and programs are consistent generally with both the national goals and the Government agency roles established by the administration policy.

But you have to realize that the U.S. Government proposals for doing research are a balance between perceptions of needed research and perceptions of precisely what the Congress will support by way of innovative research activities.

The Congress, in my judgment, must create a receptive attitude toward the research proposals presented by NASA and the Department of Defense to encourage the bold new programs required to maintain our military and commercial preeminence in the aeronautical sciences.

I appreciate the opportunity to come and discuss these issues with you and I am available for any questions you might have on my submitted testimony, any of my remarks, or any other matters.

[The prepared statement of Dr. Cooper follows:]

STATEMENT BY DR. ROBERT S. COOPER, DIRECTOR, DEFENSE ADVANCED RESEARCH PROJECTS AGENCY

Mr. Chairman and Members of the Subcommittee, I am pleased to have this opportunity to appear before you this morning. I am particularly pleased that the Subcommittee is addressing the far-sighted subject of our long-term needs in aeronautics. We who are primarily concerned with these long-term needs certainly need all of the help we can get in withstanding the considerable pressure of short-term engineering and fiscal constraints.

I intend to address specifically most of the questions which you indicated in your invitation, but before I do that, I would like to make a few general observations.

First, aircraft will continue to be a vital part of our defense structure into the twenty-first century. As you know, roughly one-third of the DoD budget is now devoted to the acquisition, operation and support of aircraft; we project that this situation will continue well past the turn of the century. I should point out that I do not believe that the persistence of this situation is due to inertia, or doing more of the same; rather, it is because there are no foreseeable replacements which offer the combination of mobility and firepower afforded by aircraft.

Second, although it is easy to forecast the need for new types of aircraft into the next century, it is obviously not possible to forecast with specificity the detailed characteristics of such aircraft. Fortunately, research and technology purposes do not require knowledge of detailed characteristics, but only of generic types of potential future aircraft. I shall indicate our vision of these generic types a little later on, but I hope that we can all avoid being drawn into lively debates as to the precise characteristics of such aircraft.

Third, we all are, I hope, convinced that there are substantial benefits yet to be gained from research and technology efforts devoted to aircraft. I believe the recent Office of Science and Technology Policy study did a more than credible job in this area. However, one point that I think deserves emphasis is that obtaining these benefits is undeniably becoming more difficult. This in turn means that long-term, well-selected research and technology efforts are perhaps needed now more than ever before. And it also means that these research and technology efforts must include more risky approaches than has been the case in the recent past.

Finally, related to the all-important area of risk-taking, I believe that our current efforts in aeronautical research and technology are critically impeded by the lack of adequate full-scale technology-demonstration aircraft to aid in the rapid transition of technology into new military and commercial aircraft lines. These "tech demos" are critical because they reduce the technical, program, and financial risk associated with full-scale engineering developments. This is particularly true of the radical new design concepts in structures, propulsion, flight control and aerodynamics that, when integrated, can provide a quantum leap ahead of our adversaries. Without the assurance of a tech demo, no prudent program manager or investor will proceed with the development of highly advanced designs. Similarly, without the existence of a tech demo as a test bed, our earlier research and technology efforts tend to be driven into areas which will not require one: i.e., short-term, low-risk endeavors. Unfortunately, the investments and risks involved are generally beyond the tolerance of private investors. Thus, it is up to the government to assume the role of providing integrated demonstrations of new technology.

I would now like to address those questions in your letter of 9 November 1983, which are pertinent to DoD.

Need and Opportunities in Military Aviation. Through studies and threat projections into the next century, we have determined that the following capabilities are required in future military aeronautical systems to counter the threat:

- Survivability
- Standoff Weapons Delivery
- Lethality
- Reduced Runway Dependence
- Real Time RECCE/INTEL
- Defense Suppression
- Battle Agility
- Rapid Deployment/Self Deployment
- Flexibility of Operations
- Hostile Environment Effectiveness
- Operational Readiness/Availability
- 24-hour/Adverse Weather Operational Effectiveness
- Affordability

In a 1981 Defense Science Board study, seventeen technologies were identified which could make an "order of magnitude" level of difference in military capability. Although many of the technologies on the list were in the aeronautics area, we conducted a similar pay-off/risk analysis and identified seventeen key aeronautics technologies which will contribute substantially to the development of military aircraft with the desired capabilities. These seventeen technologies are:

1. Stealth: the most revolutionary military aeronautics technology since the jet engine and the swept wing. Includes radar, infra-red, sound, visual and any other observable characteristic. Coupled with effective medium and long range weapons (more than 10KM) it allows extremely high survivability

and lethality. It allows one to shoot at an opponent "from the dark" without being detected.

2. Supersonic Cruise and Maneuver: a key technology which will likely be exploited in the next US fighter design. A speed advantage over an opponent, properly used, enhances survivability and lethality. The technology is being developed to allow this capability with a minimal increment in weight and cost. Coupled with advanced beyond-visual-range missiles and stealth technologies, analysis has shown favorable combat exchanges of 10 to 1 or more, far in excess of F-15 or F-16 capability.

3. High Lift-to-Drag Ratio Hypersonic Vehicles and Boost Glide Weapons: shaping of a long range weapon (reentry velocities down to Mach 3 to 4) to double its range compared to a ballistic shape, for the same weight. In addition, a 10-fold to 100-fold increase in footprint landing area is available for multiple aimpoints and flexible routing of the weapons to increase survivability to the target and lethality. This capability can be ready for the late 1990s.

4. Numerical Fluid Dynamics and Structural Optimization: exploiting the potential of current and future super computers, designers will be able in the mid-1990s and beyond, to calculate the aerodynamics, control and structural characteristics of an arbitrary body shape. This will allow designers to search for truly optimum shapes consistent with fundamental physical laws to find the best, most effective weapon system configuration. The potential is staggering for military or civil capability.

5. Thrust Vectoring/Thrust Reversal Nozzles Integrated with Control for STOL, VSTOL: a key set of technologies which, when integrated, will allow new modes of flight to enhance lethality and survivability and also allow military operations to be less dependent (and in some cases independent) on fixed airbases which are vulnerable to attack. True aeronautical system mobility, not unlike moving artillery, will become available for reasonable increments in weight and cost compared to conventional systems.

6. Lift Enhancement Aerodynamic Devices and Boundary Layer Management: current aeronautical systems are limited in their lifting capacity by wing size and flow turbulence and separation (loss of lift). Lift enhancement and flow management devices will increase lift, thereby enhancing maneuverability, payload-range, productivity, reduced field length at airports and bases, and improved efficiency. Fuel savings of 20% to 60% are feasible, for example, through use of fully laminar flow on wing and fuselage surfaces.

7. High Temperature and Advanced Metal Structures: advanced metallurgy is providing new capability for metals by extending the temperature capability of aluminum and alloys so that they can be used for sustained supersonic temperatures. Rapidly solidified technology (RST) provides improved stress levels at lower density for application to airframes and engines. Super-plastic forming and concurrent diffusion bonding of titanium and aluminum can reduce cost up to 25% and reduce dependence on strategic materials. Designers of future aeronautical systems will have a wide choice of materials to significantly reduce weight and cost.

8. Metal Matrix and Advanced Organic Matrix Composite Structures: composite structures will be in use in primary airframe and engine structure (wings, fuselage, tails, etc) by the late 1980s but these applications represent only the first generation of composites; even so, weight savings of 20% to 30% are typical. Succeeding generations of composites will use high strain fibers, advanced metal and non-metal (organic) matrix material to further reduce weight up to 50% compared to all metal structures. One of the most exciting new composites is carbon-carbon (CC) which will be capable of withstanding orbital reentry temperatures, thereby eliminating the thermal protection systems on vehicles like the Space Shuttle. Application of CC to rocket nozzles and jet engines or ramjets will significantly improve performance and reduce life cycle cost. We are just beginning to tap this field.

9. Active Adaptive Flutter Suppression: fighter aircraft with thin wings are often limited in their flight speed by flutter, which is an undesirable coupling between aerodynamics and structural response modes. One promising way to eliminate this limitation, and thereby improve aircraft survivability from hostile surface-to-air missiles, is to rapidly alter the aerodynamic shape or structural characteristics to decouple the modes. Flutter speeds have been increased 30% in recent wind tunnel tests. Flight tests in the late 1980s will verify the method and indicate further improvements. Extensions in the 1990s and beyond to even higher speeds and for new shapes will further enhance military effectiveness.

10. Laser Hardened/Ballistic Survivable Structures: due to rapidly emerging threats, future aircraft and missiles may need to be protected from laser/directed energy weapons as well as advanced ballistic (projectile/fragment) threats. Techniques for laser hardening start with the surface finish and go all through the vehicle design. This technology is essential for future systems in order to achieve a balance between performance weight, cost and survivability.

11. Advanced Rotorcraft Technologies: the Army has an extensive rotorcraft R&D program which will provide improved

capabilities well into the next century. Improvements will come in speed, maneuverability, range-payload and survivability. A family of rotorcraft will be designed for attack, recce, assault, supply, etc. Stealth technology will be applied to rotorcraft to enhance survivability. Hybrid rotorcraft fixed wing designs could allow transonic or even supersonic operation in the 1990s and beyond.

12. High Thrust-to-Weight Ratio/Low Fuel Consumption/Durable Engines: a wide application of aerodynamic, structural and control technologies will provide 25% or more increases in turbine engine thrust-to-weight ratio with reduced fuel consumption and allow extended supersonic flight operation. Special propulsion cycles coupled with extremely high turbine temperatures can reduce fuel consumption by 20 to 40 percent. The impact of these advances on flight vehicle size and cost can be truly revolutionary. Prop-fan propulsion systems for transport aircraft can reduce fuel consumption by 15 to 25 percent over large fan engines. Engine durability of critical components can be increased by 2 to 4 times over current fighter engines. Propulsion and flight control will be integrated for mission effectiveness and performance improvements along with reduced logistics and spares requirements. Nuclear engine propulsion is feasible for long endurance aircraft if R&D is resurrected from the late 1950s. Endurance of days/weeks could be achieved in the early part of the next century.

13. High Performance/Low Cost Missile Propulsion: the range of air launched or surface launched missiles can be easily doubled by application of ramjet technology over current rocket powered systems. Aerodynamic shaping can provide a re-doubling of range. Extended range ramjet-powered missiles will be capable of maneuvering all the way to the target, thereby enhancing target lethality and missile survivability. Missile cruise speeds up to Mach 6 will be available by the mid-1990s and up to Mach 12 or more by application of supersonic combustion ramjet technology in the late 1990s if R&D is properly supported. The Soviets and Europeans have had operational ramjets (up to Mach 3 to 4) for a number of years and can be expected to exploit this technology even further.

14. Safe Crew Escape for Aircraft and Spacecraft: this is a key technology to allow current and future manned aircraft--even aeronautical manned spacecraft beyond the Space Shuttle--to operate effectively and safely at extremes of the flight envelope, i.e., at high altitude supersonic flight and at low altitude high speed flight. Current ejection seats have a high fatality rate at these conditions. For spacecraft, a small "life boat" reentry vehicle is feasible to allow crew recovery from a disabled Shuttle in orbit; escape capsules are being examined for use in the 1990s or beyond to allow the crew to escape if an emergency should occur during reentry.

15. Rough/Soft Field Adaptive Landing Gear: current tactical aircraft are limited to operating on clean, hard concrete runways, the length of which is determined by the aircraft aerodynamic and propulsion characteristics. VTOL aircraft are capable of operating independent of runways, but are currently limited in range - payload. An alternative approach is to design an adaptive landing gear system that can operate from rough runways after an attack (thereby allowing rapid sorties while the runways are being repaired), or allow aircraft to taxi over grass, dirt, or other soft surfaces from the shelters to useable segments of the runway. Extensions of this technology will allow tactical aircraft to takeoff and land off the runway under certain conditions. This would make it impractical for the enemy to target the runways on a large airbase.

16. Flight-Propulsion-Weapon Integrated Control System: with digital electronics as the means of communication, it is now possible to tie together the control systems of the airframe, the engine and the weapons on the aircraft. Coupled with sensors and other avionics equipment, great improvements in performance, effectiveness and survivability are possible. Artificial intelligence will be used to accomplish some of the integration tasks, with the pilot or crew serving as executive decision makers. The integrated control system will operate as the brain and nervous system of the aircraft to accomplish its mission. This is particularly necessary in a high threat environment, or during low altitude penetration. We are just now starting to evaluate some of this level of integration in analysis, simulation and flight demonstrations, but survivability improvements of ten-fold are projected in some cases. No longer will the pilot overfly the target to drop a bomb. He will deliver it from a highly maneuverable, jinking flight path designed to minimize exposure to enemy defenses.

17. Terrain Following/Terrain Avoidance/Threat Avoidance Flight Management: current aircraft such as the F-111 and B-1 use terrain following to improve penetration survivability. With advanced flight control algorithms and sensor fusion, it will be possible in the future to not only follow the terrain, but to fly around it in order to minimize detection from ground-based defenses and maximize clutter to air interceptors. High bank angles up to 90 degrees may be required in some maneuvers to avoid the terrain. From either stored data or sensors, threats can be detected and avoided automatically or manually by the advanced tactical flight management procedure. Voice control may be used to enhance the effectiveness and reduce pilot workload in a high threat scenario. The payoffs to aircraft/rotorcraft survivability are very significant in hilly or mountainous terrain. Simulations are being carried out now, with flight demonstrations planned for the late 1980s. This

technique will keep the low altitude penetration attack option open into the next century even as defenses improve.

Research and Technology Programs. The aeronautics research and technology base programs of NASA and DoD are addressing all of the seventeen identified technologies through development of firm foundations for the technology and in many instances we are conducting or actively planning full scale technology demonstrations. These demonstrations are often conducted in cooperation with NASA. Some of our current areas of technology demonstration activity include:

- Integrated Fire/Fight Control
- Automated Maneuvering Attack
- STOL Fighter Technology Demonstrator (Vectoring, Reversing Nozzles, Integrated Propulsion/Flight Control, Soft-Rough Field Landing Gear)
- Advanced Tactical Fighter (ATF) Critical Technologies Demonstrator
- Smooth Contour Variable Camber Wing (Mission Adaptive wing)
- X-29A Technology Integration Demonstrator (Forward Swept Wing)
- XV-15A Tilt Rotor Research Aircraft
- Large Fighter Engines (Advanced Technology Engine Gas Generator, Joint Technology Demonstrator Engines)
- 5000 hp Modern Technology Demonstrator Engine
- Integral Rocket-Ramjet
- Advanced Digital-Optical Flight Control System (Helicopters)
- All Composite Helicopter
- Advanced Rotorcraft Technology Integration
- Metal-Matrix Composite Wing Panel (C-5A)
- Automatic Terrain Following/Terrain Avoidance

These technology demonstrations will yield technology availability dates in support of future military systems which are expected to emerge about the turn of the century. These technologies will provide most of the military capabilities DoD anticipates being required in the first quarter of the next century. However, there is one area which is lagging and that is in the high L/D hypersonic vehicles and boost-glide weapons. While significant aerodynamics, propulsion, structures and control technology can be developed in the laboratory, full scale demonstrations will be required before these capabilities can be realized. Just as earlier developments including the X-15, Dynasoar and lifting body research contributed to the Shuttle, so must we plan to develop technology for the follow-on to the Shuttle. Although the military worth of man in space is still being debated, we can begin to identify a wide variety of missions for which a Shuttle follow-on capability may be invaluable. These include: reconnaissance, surveillance, anti-satellite encounters, force management, satellite repair and emergency reconstitution of space based unmanned surveillance assets. This will require aircraft capable of orbital or suborbital flight. It will require space flight systems which are responsive, flexible, survivable and affordable. We have to develop the technology to have the capability to launch on short notice, with minimum turnaround and servicing--in other words develop a truly operational military transatmosphere capability.

Federal Agency Roles. I believe that the continued U. S. preeminence in both military and civil aviation is due for the most part to past government support of aeronautics research and technology. The Federal agencies through which this support has been provided, have evolved to the point where roles are well defined and the interrelationships have been extremely productive.

The U. S. is unique in that it is the only country with a major aeronautics industry, where there is an independent agency (NASA) -in addition to Defense, which is responsible for developing aeronautics technology. It is precisely through this arrangement that the U. S. has been so successful, because it provides for:

o Specific and timely military aeronautical R&T needs through DoD research and technology development and demonstration programs.

o A broad technology base through NASA programs, the results of which can be used by industry in meeting both military and civil aircraft needs.

o Free transfer of information among government and industry, and a long-term perspective free from short-term development and operational pressures, through NASA's independent status.

A common criticism of the current institutional arrangement is that it results in duplication between NASA and DoD programs. This problem is more one of appearance than of reality. Management coordination exists at all levels, the highest being the Aeronautics and Astronautics Coordination Board (AACB), which is co-chaired by the Deputy Administration of NASA and the Under Secretary of Defense for Research and Engineering. This management coordination includes joint review of programs and the development of cooperative and/or interdependent programs between the two agencies. In addition, informal coordination exists among all the technical staff on a day-to-day basis.

It is through this highly effective and well coordinated institutional framework that we would expect to initiate and execute the technology programs needed to develop future military aircraft capability.

New Facilities or Systems. The aeronautical research facilities of NASA and DoD provide a combined capability unequaled anywhere in the world. The capabilities embedded in these facilities have enabled the U. S. to develop the X-15, B-70, Space Shuttle, SR-71, XV-15 Tilt Rotor and certainly the most capable and effective military and civil aircraft in the world, both today and in years past. We expect these facilities to continue to be very productive in the future; however, as the nature of aeronautics technology changes, so too will the nature of our facilities change.

As you know, computational fluid dynamics has emerged as a tool with great potential to enhance the aeronautical design process. The capability to analyze three-dimensional flow around an arbitrary configuration will have enormous impact on future military aircraft designs, particularly as configurations depart more and more from the "conventional," for a variety of reasons. The NASA activity to develop the Numerical Aerodynamic Simulator (NAS) will provide the U. S. the most advanced numerical aerodynamic simulation capability in the world. We are working with NASA to insure that the NAS will meet DoD's needs into the twenty-first century, and to insure that the facility is secure to provide for timely application to future military systems.

We look forward to the coming-on line of the National Transonic Facility at Langley, the 40x80x120 foot wind tunnel at Ames and the Aeropropulsion System Test FAcility at the Air Force Arnold Engineering Center. Coordinated planning to develop these large scale test facilities began over ten years ago under the auspices of the AACB. We are again examining our distant future facilities needs in coordination with NASA, and while we have not identified specific new near-term facility requirements, it does appear that some selected longer-term facilities will be required for large scale icing research, integrated airframe propulsion research and advanced turboprop research. In all of these areas, altitude, temperature and speed effects are important and must be studied concurrently.

Both NASA and DoD operate a number of test bed research aircraft. At the present time these are mainly comprised of modifications of existing aircraft such as the AFTI/F-16 and the AFTI/F-111 (Mission Adaptive Wing), but also include entirely new experimental aircraft concepts such as the X-29A (Forward Swept Wing) and the XV-15 (Tilt Rotor) aircraft. Flight research will continue to play a key role in the development of aeronautics technology and will require advanced experimental aircraft in order to achieve capabilities such as short take-off and landing fighter aircraft with supersonic persistence and reduced signatures.

Is the Administration's Aeronautical Policy being implemented in an aggressive and balanced manner? The Administration's policy established challenging national goals for both aeronautics and aeronautical research and technology, and defined government and agency roles. As you know, an Aeronautical Policy Review Committee has been established, under the chairmanship of Mr. J[illegible]teiner of the Boeing Company to review government R&T pl[illegible]and programs for consistency with the policy. In Dr. DeLauer's place, I participated in the first meeting of this Committee last August, and I am in general agreement with the findings and recommendations of the Committee, which Jack Steiner has already reviewed with you. At the risk of being a little repetitious, I would like to emphasize a few of my personal views.

I think that the current government R&T plans and programs are consistent with both the national goals and the government agency roles established by the Administration's policy. So to this extent the policy is being implemented.

However, these plans and programs are not consistent with an aggressive and balanced implementation of the Administration's policy. Our programs must include more truly long-range efforts, more sharply focussed on high-payoff, high-risk areas if we are to achieve technical progress at a pace sufficient to keep ahead of our adversaries. Achieving such an aggressive program will require not only setting more specific long-range goals, based on a reasonable vision of the future, but also that both DoD and NASA set their priorities accordingly.

As I indicated earlier, our current plans and programs suffer from the lack of full-scale technology demonstration aircraft, and this lack of balance both drives what should be long-term efforts into being short-term ones and simultaneously prevents the transition of really advanced technology into operational aircraft whether they be civil or military. In my view, a new line of experimental aircraft (X-aircraft) should begin immediately. We should set as our goal the start-up of two new X-aircraft technology demonstrators each year until they can no longer be justified on the basis of technology which needs to be demonstrated or developed in full-scale configurations. This will require additional investment, of course, but I believe it is an economical way to provide the long-term, high-payoff, high-risk focus that we need to maintain a strong America; competitive in both the world geopolitical and economic spheres. Thank you again for this opportunity to give you my views on aeronautics research.

Mr. GLICKMAN. First of all, what's your relationship with the NASA aeronautics program, generally? I mean, are you the lead coordinating agency in the Department of Defense or does the Air Force deal directly with NASA separately and you find out about things afterward or——

Dr. COOPER. All of the above. The Defense Department is a very large organization and it has aeronautics research going on in the Army, the Navy, the Air Force and at the Defense Advanced Research Projects Agency.

We have a coordinating mechanism for coordinating research, both within the Department and between the Department and NASA. That coordinating agency is called the Aeronautics and Astronautics Coordinating Board, and through that Board and its various subcommittees, we coordinate strongly from the top down point of view on all of the aeronautics research that's going on in Defense and in NASA.

In addition, the services independently work with NASA on individual programs and coordinate at the very detailed level the program actions that are being taken, establishing in many cases, joint programs, as does DARPA.

DARPA also has joint programs with NASA and a perfect example of that, again, is the X-wing aircraft program, which we have established jointly with NASA to explore a radical new very high risk, but potentially very high payoff of vertical takeoff and landing aircraft technology.

Mr. GLICKMAN. What would be your judgment on regenerating a modern-day research airplane program?

Dr. COOPER. Well, I guess I'm among the few people who would strongly favor renewed interest in research aircraft, but I'd have to point out that when I talk about a research aircraft program, I'm not in accord with Hans Mark's view of that any more than I am with Chuck Yeager's. Chuck Yeager's view largely is aimed at hypersonic aircraft exploring the highest velocity and highest altitude, highest mach number regimes.

My view is that to serve both commercial and military interests, there are other dimensions of performance that must be probed by our new research aircraft and that's why DARPA has particularly worked to create new testbeds, new flying research aircraft testbeds, over the last few years that begin to explore some of these new performance dimensions, examples being the X-29 and the X-wing programs.

I believe that we need to create flying testbeds, research aircraft, if you will, that look at some of the issues that explore the low-speed, high-angle-of-attack regimes of the flight envelope, that pay particular attention to short takeoff and landing, short takeoff and vertical landing, and vertical takeoff and landing aircraft.

These are particularly important aircraft for the future of military aviation in my judgment, and unlike Hans, I am fond of the idea of integrated technology demonstrators, where instead of exploring one particular technology in a particular demonstration aircraft, we try to incorporate maybe three or four separate technologies, each one of which may be a 25- or 50-percent improvement over existing technology into one airframe to find out whether we can actually make order of magnitude jumps forward in capability.

In my judgment, the X-29 comes very close to that, incorporating about four or five radical new technologies in one aircraft that could provide an extraordinary new military capability for the 1990s. I believe that we should pay particular attention to that kind of research aircraft and we should have more of them. I believe that the Defense Advanced Research Projects Agency should not be the only agency of the Federal Government that is favored by the Congress to create such flight demonstrators, either.

I believe that the military services and NASA all ought to sponsor integrated demonstrations of capability of this sort.

Mr. GLICKMAN. We would, but the fundamental fact of life is that the money seems to be available in one source more than in another source, and you know, this, of course, goes back to the basic question of relating the military research into the civilian sector as well, and doing it generically. You all seem to be more favored under this administration to get some of those moneys and that's why I'm so happy that you're here because I think that you can—you can do us a reciprocal favor by insuring the survivability of an independent research center like NASA, who can be doing a lot of the basic work that might have military, but also civilian applications as well.

After all, one of the functions of NASA is to help you, not just to help the civilian sector.

Mr. COOPER. Well, I agree, Mr. Chairman, but I think that NASA does have a role to play in these experimental research aircraft as well, and you can see the payoff.

In fact, we would not have a JVX program today if the XV-15 had not been experimented with, as Dr. Mark mentioned in the 1960's and 1970's, and I believe that there is significant military payoff in that, so I think that the commercial and military significance of the tilt-rotor, tilt-fan aircraft, are important in both spheres. NASA is the logical area where that ought to be done.

Just let me come back to your comment about DARPA being the only agency favored with funds.

I think that we have a situation here where the Department of Defense and NASA quite often point at the Congress and say, "The Congress is not living up to its responsibility to provide funds for research aircraft." The Congress points to the OMB and says the OMB is the culprit. OMB points to the other agencies of Government and the deficit as being the culprit.

The fact of the matter is that we should all to get together and decide what's in the national interest. I believe that there is a strong and abiding reason for us to sponsor research aircraft.

By and large those research aircraft are beyond the financial capability of the industry to support. They cost, as in the case, for instance, of the X-29, on the order of $100 to $150 million just to build the airframe and to get it to work the first time, and typically there may be $20, $30, $40 million a year required for a few years to determine the full potential of the technologies through experimental flights of these airframes.

So, you are talking about a couple hundred million to a quarter of a billion dollars of investment in each one of these research aircraft. That's far beyond the capability of even a Boeing or a Douglas aircraft to support on spec; that is, the X-29, even though it looks like a fighter plane, is not a fighter plane, could never be used as a fighter plane, but certainly could be used to test the technologies that might be put into say the advanced tactical fighter of the 1990's.

Can you imagine a company so large as to invest $250 million to find out what the potential of an integrated series of technologies might be in a single airframe? I can think of only one source of capital to give us as a nation the capability to do that kind of exploration, and that is the Federal Government. So, the Federal Government does have a role to play, and that role exists not only at the Defense Advanced Research Projects Agency but also in the military services and at NASA.

Mr. GLICKMAN. Hans Mark, when he mentioned his three or four dream areas, one of them was an airplane that would be dropped out of the space shuttle that would be used to explore that very high altitude, high-speed envelope that might be involved—and he said might—in space warfare or antisatellite war—you know, antimissile warfare, in line with the President's speech.

Is this one of the things that you are contemplating right now?

Dr. COOPER. Well, currently defense has no mission for a hypersonic aircraft. As a matter of fact, as you recall from General Yeager's testimony, aircraft for fighter aircraft purposes in a regime beyond about mach 2 really have little or no utility. Aircraft that engage one another at whatever speed ultimately end up in their final throes of engagement with one another in subsonic regimes.

And so, supersonic aircraft beyond about mach 2 are probably of little or no utility for the military. That conclusion is further enhanced by the rapid rate at which missiles are getting smarter; that is, missiles can be used in the regimes beyond mach 2 where that is required for terminal engagements.

So, the only question is what about the hypersonic regimes that deal with mach 7 to mach 20 flight. Currently there is little conceptual view of how such flying machines might be used.

But in my view, that shouldn't deter us at all in terms of exploring that flight regime. As a matter of fact, I think if we had continued to explore that flight regime in the 1960's and early 1970's as we should have, we wouldn't have had nearly the difficulty in developing the space shuttle as we did and probably could have saved ourselves literally hundreds of millions, if not billions of dollars to clear up some of the hypersonic flight regime problems that had to be invested in during that program.

Mr. GLICKMAN. It would seem that apart from the military applications the civilian applications would be to give us more readily—more ready access to a space station, a space environment and the Earth that would have been possible had the X-15 been permitted to continue.

Dr. COOPER. Yes; I believe that's true.

There is one other thing, and that is that the dream of a flying vehicle—that is, one that can take off and fly on its own energy into orbit and return—is a dream that we should pursue at the technology level and reasonably vigorously because there are some tremendous payoffs to be gained there.

Particularly the one military payoff is the vulnerability of our launch systems today. We are rapidly approaching the time when we will be totally reliant upon three launch pads—one located on the west coast and two located here on the east coast in Florida—for getting all of our military and civilian payloads into Earth orbit.

And in this way, we are submitting ourselves to a tremendous vulnerability because of the fact that those three targets could completely put us out of the space business if they were attacked by an adversary and for very long periods of time, since the facilities are difficult to rebuild once heavily damaged.

So, the ability to take off from any nominal 10,000- to 15,000-foot runway in the United States and make it to orbit with a substantial payload and return safely could be of great benefit in times of duress for this country and the ability to move that launch facility around—that is, to take that single stage to orbit and put it in locations around the country where it cannot easily be found—would keep that capability secure from potential adversaries.

Mr. **GLICKMAN**. Thank you very much. I appreciate your testimony.

Our final witness is a panel: David Jenney with Sikorsky, Roger Schaufele with Douglas, and Chet Rembleske with Beech Aircraft. Why don't all you gentlemen come up to the front, and I think probably we will take it in the order that they are listed, so that would be Sikorsky, Douglas, and Beech. Dr. Jenney, why don't you begin—Dr. Jenney.

STATEMENTS OF DR. DAVID S. JENNEY, CHIEF, TECHNICAL ENGINEERING, SIKORSKY AIRCRAFT; ROGER D. SCHAUFELE, VICE PRESIDENT, ENGINEERING, DOUGLAS AIRCRAFT CO.; AND CHESTER A. REMBLESKE, SENIOR VICE PRESIDENT, ENGINEERING, BEECH AIRCRAFT CORP.

Dr. **JENNEY**. Mr. Glickman and staff, I welcome this chance to give you our view of the future of aviation. I will abstract from the testimony that has been submitted.

The helicopter industry is still young as industries go, and we expect the excitement of our coming of age to go on for many years yet. I want to stress four aspects of our industry's future this morning, and there is more detail in the written text.

First, that technology is advancing very rapidly in our industry; second, that as gains are made we particularly expect to see gains in making helicopters unobtrusive, good neighbors; third, that there will be totally new uses for helicopters that we haven't seen yet; and finally, new concepts—departures from conventional helicopters, if you will—should establish their place in the next two decades.

First, the technology payoff. Traditionally, technology advances are very quickly adopted and used to advantage in the helicopter business. The requirement for vertical takeoff puts a premium on weight saving and demands more power and more control.

Some of the important technologies that will pay off are clearly visible today. Advanced composite materials already provide savings of about 20 percent in structural weight, and they reduce manufacturing costs. New fibers and new resins appear every month as the suppliers and the designers pursue the advantages of designing the material, as well as the part it is made into.

Microelectronics may have an even more far-reaching effect than composites. An onboard microprocessor handling large amounts of information from advance sensors and displaying necessary information to the pilot will permit safe accomplishment of missions that were previously impossible.

The long-sought goal of all-weather flight with remote area navigation, onboard system condition monitoring, all these are within reach. In addition, fiberoptics to replace wires promised to reduce the susceptibility to lightning and electromagnetics; more advanced rotors will improve efficiency, reduce the number of parts and give a smoother ride; and engines with even better fuel consumption are coming with power rating systems changed to fit better the helicopter's needs. The cumulative effect of these technologies should reduce operating costs by at least 20 percent per decade for at least the next 30 years.

Sikorsky has many actions underway to get ready for the new technology. For example, we've made a major commitment to advance composites. This began with a heavy use of composites in the S-76 helicopter, and we've just announced plans to build a separate composite factory. The intent is to build our parts in a modern plant and also to sell our design and fabrication expertise to others outside the helicopter industry and provide the means of staying at the forefront of this fast-moving technology.

Sikorsky is also adding to its plant in Stratford new improved facilities for our engineering staff. Of this 280,000 square foot, three-story addition, one floor will be for new engineering laboratories for the integration of advanced microelectronics in our future aircraft.

Now, helicopter obtrusiveness. This has become recognized as a damper to the growth of applications and sales of our product. Obtrusiveness as I use it here encompasses perceived negative attributes of the helicopter: safety, noise, and vibration particularly. In each of these areas, great gains have been made but much more progress is needed.

The helicopter operates close to population centers. It maneuvers close to the ground, and it lands and it takes off on the average every 15 minutes. It has an unusual responsibility to be a good neighbor. If it isn't, the helicopter will be unable to realize its full potential.

Improved helicopter safety always tops the list. Many of the pilot error type accidents result when the aircraft is engaged in particularly challenging tasks, in adverse weather, close to obstacles, that sort of thing.

Developments in microelectronics can simplify many of these tasks by giving the pilot better displays, more visibility from a simplified cockpit, and a more stable, controllable aircraft.

Equipment failures cause a minority of accidents, but they are of great concern, obviously, to the manufacturer. It's been a goal for many years to make aircraft more fail-safe or damage tolerant, and now developments in composites, in fracture mechanics and in advanced sensors will make it possible to apply this approach to more of the essential helicopter components.

Helicopter noise bothers everyone to some extent. The military would like less detectable helicopters, communities threaten to bar their intrusion. Regulating agencies are holding our feet to the fire to meet noise standards. Now industry and NASA have jointly turned on a significant R&D thrust to understand and solve the problem, and we expect to succeed.

To the helicopter passenger, obtrusiveness means internal noise and vibration. Some of today's newer helicopters show that these problems can be solved. The thrust now is to reduce the cost and the weight of a smooth, quiet ride and extend it to higher speeds.

Today we expect that powerful computers, backed by careful test results, can cope with these problems, too. Helicopters by the year 2000 should be an accepted good neighbor, safer, quieter, and smoother.

New helicopter markets, which will appear by the year 2000. Helicopter public service, such as emergency medical service, will keep growing. Corporate and taxi service use of helicopters is growing with better ride quality that is now available. There is a whole list and some examples in the written text of potential missions that are rarely done by helicopters today but that will become more viable.

Some of these missions are suggested by known changes in the environment. For example, navigation capability, especially in remote areas, will improve. As the global positioning system, GPS, of satellite reference points is put in place, aircraft will be able to locate themselves in three dimensions within a few feet anywhere in the world. This is especially beneficial to helicopters that can do many jobs in remote areas. This capability, combined with an all-weather cockpit, could open up totally new services to be provided by helicopters.

Finally, let me address advanced concepts. The VTOL industry has a long history of research and experimentation with advanced concepts. After 40 years of exploration, however, the helicopter in its various forms and the AV-8B Harrier are the only types in production.

Our past lack of success, however, does not presage the future. Technology had to advance to bring the other VTOL concepts from the possible to the practical, and this now appears to have happened.

Sikorsky's advancing blade concept makes a good case in point. When this rigid, coaxial rotor helicopter was invented, it was only feasible even for demonstration with the use of titanium in the main rotor blade spars. Steel or aluminium would have been too heavy.

The demonstrator then flew with titanium spars, the first in the industry, and with a complex mechanical control system. That demonstrator aircraft works well, and it did its job, but it can't carry enough load to do a useful mission. Now, with advanced composites and new structural concepts, large weight savings are possible. With digital automatic flight controls, the control complexity can be removed.

And the ABC is a viable candidate for missions that need its combination of attributes: Outstanding low-speed performance and handling qualities, a speed capability of over 250 miles per hour, and a very compact configuration. It looks like a good candidate for the Army's light scout attack, LHX mission, as configured here or for possible future use in public service applications, like emergency medical service.

The most visible new VTOL type today is the tilt rotor. This concept has been flying since the mid-1950's, but new technologies were needed to make it really viable. Again, lighter structures make its useful load more attractive and advanced control systems unburden the pilot through the VTOL flight.

In addition, development of the tilt rotor has benefited from the evolution of modeling techniques for understanding complex dynamic and aerodynamic systems. Modeling and preliminary design of the JVX tilt rotor will in the next 2 or 3 years define the aerodynamic efficiencies of the concept and the weight empty fractions that are achieved with new technology materials.

The newest VTOL concept is the X-wing, as mentioned earlier. Schemes for stopping a helicopter rotor in flight have been studied for years, but no one has done it yet. Now the X-wing concept promises to do that for the first time.

The X-wing rotor will stop its four blades with two pointed forward at 45 degrees and two aft at 45 degrees. Several small models have been tested in the wind tunnel. A 25-foot rotor has been tested in NASA's Ames 40 by 80 wind tunnel.

Now a 50-foot rotor is being built to be tested on the NASA/Army rotor systems research aircraft, shown here in the model. This test is significant in several ways. The use of the RSRA for rotor flight research in lieu of building a new aircraft on which to test each new rotor is aimed at reducing program schedule time and risk.

This is the first application of that development concept. When X-wing converts from a rotor to a wing in flight, a major milestone will have been passed. We will have demonstrated the first helicopter that is also a high-speed airplane with no obvious upper limit on speed. It won't hover as well as a helicopter or dash like a jet fighter, but if offers a capability for missions that need some of each.

In addition to ABC, tilt rotor and X-wing, other concepts continue to receive attention. The list is long. Many have been studied before, but the technology wasn't ready. In the next 20 years we should establish which have a place.

So, to recapitulate, the rate of change of technology in the helicopter or V/STOL field is still very high. The result is that helicopters as we know them will improve significantly over today's products by the year 2000 and that one or more of the advanced VTOL concepts will establish its place in the family of aircraft types.

A major thrust of the improvement in helicopters will be that they become better neighbors: quieter, safer, and smoother. The result of all this will be not just the expansion of the missions and uses we see today, but also the development of new uses we haven't thought of yet.

At Sikorsky we are excited about the future, obviously, and dedicated to helping lead the industry to provided increase service and capability in the next century.

Thank you.

[The prepared statement of Dr. Jenney follows:]

TESTIMONY BY DR. DAVID S. JENNEY, CHIEF OF TECHNICAL ENGINEERING, SIKORSKY AIRCRAFT DIVISION, UNITED TECHNOLOGIES

SIKORSKY AIRCRAFT'S VIEW OF THE FUTURE OF AVIATION

Good Morning. Thank you for this opportunity to tell briefly of Sikorsky Aircraft and the helicopter industry's view of the future of aviation. The helicopter industry has now celebrated its fortieth birthday, but it is still young as industries go, and we expect the excitement of our coming-of-age to go on for many years yet. I want to stress four aspects of our industry's future this morning.

First - Technology is still changing rapidly in the helicopter industry. Even a conservative estimate today can show operating costs cut by over 1/3 in 20 years. New materials, microelectronics, computer-aided design and manufacture, and the constant feedback of lessons learned from the growing helicopter fleet all nourish our drive to make helicopters affordable and more "user friendly."

Second - Besides operating economy, we expect to see big gains in making the helicopter unobtrusive. The passenger will get a smoother, quieter ride, and the public will see and hear a quieter neighbor with a better safety record.

Third - Part of the change over the next 20 years will be in the markets served. We have not done a very good job of anticipating new markets. Offshore oil found the industry unprepared. The emergency medical applications have grown beyond expectations. We must be more perceptive about the year 2000.

Finally - New concepts - departures from the conventional helicopter, if you will, - will probably establish their place in the next 2 decades.

Technology Pay-Off

Traditionally, and with good reason, technology advances are quickly adopted and used to advantage in the helicopter business. The requirement for vertical take-off puts a premium on weight saving, and demands more power and more control. The useful load of today's helicopters is up to 50 percent of gross weight, from 30 percent or less in the 50's. That is still low by fixed wing standards, however, and will always be lower because a premium will always have to be paid for the ability to land and takeoff vertically. As a result, each percent taken out of the empty weight of a helicopter results in a percent gain in useful load, or a two or three percent gain in payload. For this reason, helicopters were quick to adopt advances in engines and new materials like titanium.

An added challenge to vertical flight is the control and stabilization required to move about in all directions. This has always led to somewhat greater piloting difficulty, but it, too, is susceptible to improvement through technology. Therefore, helicopters were quick to adopt stability augmentation systems and now have moved on to digital automatic flight control for many missions. Safe, efficient vertical flight has been a great technological challenge, so the helicopter/VTOL field welcomes and uses new technology with a receptiveness probably matched only in that other VTOL business - space flight.

Some of the technologies that will shape production VTOLs in the year 2000 are clearly visible today. Advanced composite materials already provide savings of about 20 percent in structural weight and reduced manufacturing cost. New fibers and resins appear each month as suppliers and designers pursue the advantages of designing the material as well as the part it is made into.

Microelectronics will probably have a more far-reaching effect on helicopters than even composites. By processing large amounts of information from a variety of sensors, and displaying necessary information to the pilot, the processor permits the pilot to undertake safely missions that were previously impossible. The long-sought goal of all weather flight with remote-area navigation, voice-commanded controls, on-board system condition monitoring - all these are within reach. As we reach for them, the content of our product changes. Already we have military helicopters in production with 50% of the value resulting from the primarily electronic, installed systems. And this figure will grow.

While composites and microelectronics probably will have the broadest effect on our business, they are not the only changes. Fiber optics to replace wires promise to reduce susceptibility to lightning and other electromagnetic interference in future, sophisticated aircraft. More advanced rotors are coming with better aerodynamic and structural concepts to improve efficiency, reduce the number of parts and give a smoother ride. Engines with even better fuel consumption are coming, and mundane though it sounds, power rating systems will change to better fit helicopter needs by providing short-term emergency ratings for improved safety in multiengined aircraft.

The cumulative effects of these technologies, without what the general public might consider a breakthrough, are projected to reduce operating costs of helicopters by about 20 percent per decade for at least the next 30 years. Since a new "generation" of helicopters only comes along every 20 years or so, a 20 percent gain per decade or 40 percent per generation is significant. I'll say more later about steps being taken to shorten the time between these helicopter "generations." One significant contributer to the cost reduction of future helicopter operations is improved reliability and better maintainability. Some of this comes from simpler, more sophisticated components. At least equally important is the fact that users and manufacturers are learning from the expanding fleet of helicopters now in operation. The lessons learned - from accidents, from failed parts, from unhappy passengers or pilots, from smart mechanics - lead to valuable improvements in the next design. Now that we've gotten beyond the basic stage of making helicopters work, this feedback has become more sophisticated and more demanding.

A separate area of technology that will impact price rather than performance, is manufacturing cost reduction. New materials and processes are taking the labor content out of more complex parts. A broader effect on manufacturing will come from CAD/CAM, computer-aided design and manufacture. A few parts are already being produced by computer-guided machines that use design information directly, without intervening drawings. This has only begun. The payoff will take place in many industries. However, the helicopter business, with relatively limited production runs of 200 to 2000 copies of any one model, should be a major beneficiary of reduced set-up time and cost.

So, what is Sikorsky doing to get ready for this new technology? Time won't allow treatment of all the actions underway, but three major thrusts deserve comment. Sikorsky has made a major commitment to advanced composites. This began with heavy use of composites on the company-funded S-76 helicopter development. It continues today with the All Composites Aircraft Program (ACAP) derived from the S-76 for the Army, and with composite applications to main rotors and other dynamic components. As you are probably aware, Sikorsky has recently announced plans to build a separate composites fabrication facility in Alabama. The intent is not only to build our parts in a modern plant, but also to sell our design and fabrication expertise to others outside the helicopter industry. This will represent both a new secondary business for Sikorsky and a means of being sure we stay on the front edge of this fast moving technology.

Secondly, Sikorsky is adding to its plant in Stratford, Connecticut new facilities aimed specifically at enhancing the capability of our Engineering and Manufacturing Engineering staffs. Of this 280,000 square foot addition, 50,000 square feet, will be dedicated to new engineering laboratories aimed at the integration of advanced microelectronics in our future aircraft. There will be flight simulators, for example, and an avionics integration lab where system components can play together before they go in an aircraft. At present, the focus for this laboratory is the Army's LHX program. Current IR&D, and capital equipment plans are aimed at positioning ourselves and our eventual partners in the program with the tools it takes to produce the best solution to this Army need. It has been estimated that the data processing requirements on the LHX - an 8,000 lb light scout/attack helicopter that will enter service early in the next decade - will be 2-1/2 times the requirement on the new AH-64 Apache gunship.

The third major new thrust at Sikorsky is in the factory. Our "factory of the future" is coming into place, in phases, to an overall plan that will reduce the cost of our product line over the next 10 years. We are fortunate to have four different production models, the S-76, UH-60 BLACK HAWK, SH-60 SEAHAWK and the CH-53E, all near the beginings of their life cycles. A typical helicopter should be in production for at least 10 years, and many have gone over 20. If we do a good job keeping these new models up to date and affordable, their production runs should go out beyond 1990, and steps taken now to produce them more efficiently will pay off in savings to our customers, including the U.S. Government. The leading elements of this "factory of the future" are in place. Our first robotic riveting is now on line; group technology is being applied in the establishment of new machining cells, and wiring harness production has been highly automated in a totally new facility in neighboring Shelton, CT.

Helicopter Unobtrusiveness

We usually talk about technology improvements in terms of performance, speed, payload or perhaps cost of ownership. There is now another direction in which the helicopter industry is placing strong emphasis. Helicopter "obtrusiveness" has become quite widely recognized as a damper on the growth of sales and applications of our product. "Obtrusiveness" as used here encompasses many of the negative, fairly subjective attributes of the helicopter-safety, noise and vibration for example. In each of these areas, in fact, great gains have been made in the past 20 years, but much more progress is needed. The helicopter operates in relatively close proximity to population centers; it hovers and maneuvers close to the ground and lands and takes off, on the average, every 15 minutes. It has an unusual responsibility to be a good neighbor. If it isn't, the helicopter will be unable to realize its full potential. Industry (not just Sikorsky) and government have recognized this problem area and a major thrust is underway.

Improved helicopter safety always tops the priority list. Great gains have been made through use of multiengines, more rigorous development programs, fault detection systems, simulator training and fail safe design. Most accidents result from "human error" (pilot or maintenance personnel). Design for simpler maintenance will help. Many of the "pilot error" accidents result when the aircraft is engaged in particularly challenging tasks - in adverse weather, close to obstacles, carrying external loads or operating in turbulence.

Developments in microelectronics can simplify many of these tasks by giving the pilot better sensors and displays, more visibility from a simplified cockpit and a more stable and controllable aircraft. Improved safety is a major goal of the advanced cockpits coming in the next generation of helicopters.

Equipment failures cause a minority of the accidents, but they are of great concern to the manufacturer. It has been a goal for many years to make all aircraft "fail-safe" or damage tolerant, and now developments in composites, in fracture mechanics and in advanced sensors will make it possible to apply this approach to more of the essential helicopter components.

Not all components can be made redundant (a main rotor shaft for example) such that total fracture can be tolerated. Fail-safety may be provided in such cases by designing to be sure that any damage to a component will not propagate to failure before it can be detected and repaired or replaced. It is well established that many composite materials are inherently more damage tolerant. By combining that attribute with advanced sensors and signal processing, important new approaches to damage tolerance will be possible. This is an area receiving increased attention both by researchers and by regulating agencies intent on being sure the user community gets all the safety that can reasonably be provided.

Helicopter noise is popular with almost no one. The military would like less detectable helicopters. The public in the neighborhood of helicopter operations becomes annoyed at their distinctive sound. Communities threaten to bar their intrusion; regulating agencies are holding manufacturers feet to the fire to meet noise standards. Industry and NASA have jointly turned on a significant R&D thrust to understand and solve the problem. Reducing the noise of the conspicous "bad rotor" is easy. Lower rotor tip speeds, as used on some of today's designs, eliminate much of the distinctive impulse noise. The goal, however, requires more than that. It quickly becomes evident that the sources of helicopter noise are very complex and not readily susceptible to analysis. Therefore, a two-pronged approach is underway to experimentally and empirically develop quieter aircraft design features while, simultaneously, the research community develops the necessary understanding and analysis of noise sources. This effort will call for new testing facilities. Sikorsky has already completed a noise measurement range at our West Palm Beach, Florida Test Center. Techniques for testing at model scale are being studied, though in this country there are currently no suitable facilities for careful tests at small scale. This will probably be a relatively long term effort, with some early gains followed by refined solutions that stretch over the next 10 to 15 years. With noise a major parameter in public acceptance of helicopters, the potential gains are worth the effort.

To the helicopter passenger, "obtrusiveness" means internal noise and vibration. Some of today's newer helicopters show that these problems can be solved. The thrust over the next ten years will be to reduce the cost and weight of a smooth, quiet ride and extend it to higher flight speeds. To date, helicopter noise and vibration have not been "designed out." They have been fixed by add-on features once the aircraft flew. The reason for this was simply that analysis of the mechanisms involved was too complex. Now we see renewed hope that powerful computers, backed by careful test results can cope with these problems too. Several design approaches to eliminating nose and vibration are available once we really understand their origins.

The helicopter, by the year 2000, should be an accepted good neighbor - safer, quieter and smoother.

New Helicopter Markets

Our industry does not have a very good record for anticipating where our products will be used. The flying crane for lifting heavy loads externally was introduced in the late 50's and the capability has seen only modest application. On the other hand, the boom in helicopter use for transportation to off-shore oil rigs was unanticipated and found the industry rushing to produce a suitable product. Recently, emergency medical service (EMS) usage has grown from an occasional part-time job to a major market. Which markets will appear by the year 2000, and how do we get ready?

There are some clues in the present trends and in emerging technologies and emerging demands. Helicopter EMS will continue to grow. Estimates (by NASA) show that tens of thousands of trauma victims could be saved each year in the U.S., and the reasonable value placed on those lives greatly exceeds the costs of the service.

Corporate and taxi-service use of helicopters is growing even in the recent economic downturn. This is probably the initial response to the new generation of smoother, quieter aircraft. As the quality of the ride continues to improve, this application for the aircraft should continue to grow.

There is a whole list of potential civil and military missions that are rarely, if ever, done by helicopters today, that will become more viable with the technology of the year 2000. For example:

- Inter-city transport: With operating costs down 20% per decade, and a smoother, quieter ride
- Search and Rescue: Longer ranges, including civil applications, with faster, more efficient aircraft
- Heavy external lift: With reduced costs and advanced flight controls for precision operations. This could extend to Vertical Onboard Delivery (VOD) to ships at sea and to multi-lift (two or more helicopters moving one very large load).

- High speed assault transport: With more speed and reduced detectability.

- Air-to-air combat: With more agility, and advanced cockpits and flight controls.

Some of these missions are on the list as candidates for increased importance because of known changes in the environment in which helicopters operate. Military uses will sometimes respond to known Russian capabilities like their high speed Hind gunship. The more sophisticated battlefield of the future is expected to put a premium on low detectability. The vehicle which is not seen or heard (by any available detector) will survive, and this factor could drive the selection process that decides what types of vehicles will take what missions. We must also have vehicles prepared to survive in the NBC (nuclear, biological, chemical warfare) threat environment. This probably won't distinguish between concepts, but it may drive the selection of materials, methods of construction and the electro-optical architecture of the integrated installed systems.

The civil environment, too, will change. Congestion of ground transport is unlikely to improve. We are still learning that just maintaining the ground transportation infrastructure is expensive. Improving it faster than the needs grow will be most difficult. While helicopters don't need roads or tracks, they do need a place to land. The orderly development of a suitable heliport network is not at all assured. Industry, the operators and all levels of government need to keep pressing to provide operating sites to take advantage of the flexible, efficient transportation mode that will be ready.

Another important change to both civil and military operations will be in navigation capability - especially in remote areas. As the Global Positioning System of satellite reference points is put in place, aircraft will be able to locate themselves in three dimensions within a few feet, anywhere in the world without assistance from the ground. This will be especially beneficial to helicopters/VTOL's since they can operate and land almost anywhere, and often will be doing a job for away from any hub of transportation. This capability, combined with an all-weather cockpit and flying qualities could open up totally new services to be provided by helicopter, and of course new markets for manufacturers.

Advanced Concepts

I've left advanced concepts for last though they are often the first concern when we think out as far as the year 2000. The VTOL industry has a long history of research and experimentation with advanced concepts. After 40 years of exploration, however, the helicopter in its various forms remains the only production VTOL, with the sole exception of the AV-8B Harrier (direct jet lift fighter-bomber).

Our past lack of success does not presage the future. As mentioned earlier, vertical take-off is more demanding than conventional take-off so lighter, more powerful, more controllable solutions are needed. Technology had to advance to bring other VTOL concepts from the possible to the practical. This now certainly appears to have happened. Powerplants are lighter, more reliable and more efficient. Structures, as noted, are getting lighter quite rapidly. Automated and/or augmented stability and control are more and more powerful with small on-board computers, fail-operational redundant electronic or optical flight controls and vastly improved cockpits and displays.

Sikorsky's Advancing Blade Concept (ABC) makes a good case in point. When this rigid, coaxial rotor was invented in the 60's, it was only feasible, even for demonstration, because of the use of titanium in the rotor blade spars. To provide the necessary stiffness in steel or aluminium would have cost exhorbitant weight. The demonstrator then flew (in 1973) with titanium spars (the first in the industry) and with a conventional mechanical (but complex) control system. That demonstrator aircraft proved the principles on which it was based, but it could not carry enough load to do a useful mission. Now, with advanced composite materials and new structural concepts, large weight savings are readily achievable. With digital automatic flight controls, most of the control complexity can be removed. The ABC has become a viable candidate for missions that require its combination of attributes - helicopter-like low speed performance and handling qualities, a speed capability over 250 mph and a very compact configuration. It looks like a good candidate for the Army's LHX mission and for future public service applications.

The most visible new VTOL type on the scene today is the tilt rotor. This concept is hardly new; it has been flying since the mid 50's. Several of the new technologies were needed to make it really viable. Again, lighter structures and engines will make its useful load more attractive, and advanced control systems will unburden the pilot through the demanding VTOL and transition flight modes. In addition, development of the tilt rotor has accelerated and has benefited from the evolution of modelling techniques for understanding complex dynamic/aerodynamic systems. The use of dynamically scaled models of rotors, propellers and wing structures on wind tunnel models is now an accepted technique for reducing development risk. The approach was used successfully on the XV-15 tilt rotor development, and it is being used extensively in the JVX design process now underway. This technique, which was also used on most recent helicopter rotors, can generally accelerate the long term progress of the VTOL field since it permits trial-and-error developments without the need for full scale test. JVX modelling and preliminary design will, in the next 2 or 3 years, verify the aerodynamic efficiencies of the tilt rotor concept and the weight empty fractions that are achievable with new-technology materials. Of all VTOL types, the tilt rotor appears to offer the best transport efficiency. For long range missions it will be superior to a helicopter. Up to some range, its VTOL and short take-off capability will make it superior to a conventional airplane. Current development efforts will establish where those crossover ranges (helicopter-to-tilt rotor and tilt-rotor to fixed wing) really are.

The newest, and perhaps most exciting new VTOL concept is the X-Wing. Schemes for stopping a helicopter rotor in flight and flying out to high speed as an airplane have been studied for years, but no one has done it in flight. Now the X-Wing concept promises to do that for the first time. The X-Wing rotor will stop its four, very rigid blades with two blades swept forward 45° and two swept back 45°. The blades (wings) derive lift principally by circulation control by thin jets of air blown out of the trailing edge of each blade over a carefully shaped Coanda surface. Since two of the blades end up flying "backward", each blade has slots for blowing from either leading or trailing edge, and the flow to the two slots is controlled to manage the lift during the different flight regimes. X-Wing development calls on many aspects of new and developing technology for its success. The stiff blades need advanced composites, and in fact will use extra high modulus graphite in a high temperature resin to handle the hot air passing through the blade. A new data base on circulation controlled airfoils has been developed for this rotor. Aircraft maneuvers, as well as rotor-induced vibration, will be controlled by variations of circulation-control blowing. The pneumatic control system and electronic feedback systems to manage those functions represent another sophisticated application of advanced microelectronics.

Several small model X-Wing rotors have now been tested to verify the concept and develop necessary analyses. A 25-ft model rotor was tested in the NASA Ames 40 x 80 ft wind tunnel in 1979. Now a 50-foot rotor is being built for test on the NASA/Army Rotor Systems Research Aircraft (RSRA). This test is significant in several ways. The use of the RSRA for rotor flight test (in lieu of building a new aircraft on which to test the new rotor) is aimed at reducing program schedule time and risk. If this approach works, and there's every reason to expect it will, the years required to bring a new concept to production readiness should be significantly shortened. When X-Wing converts from a rotor to a wing in flight, a major milestone will have been passed. We will have demonstrated a concept for a good helicopter that is also a good high speed airplane - with no obvious upper limit on speed. It will not hover as well as a helicopter, or dash like a pure jet fighter, but it offers a new capability for missions that need some of each.

In addition to ABC, tilt rotor and X-Wing, other concepts continue to receive attention. The compound helicopter-wings or propulsion added to a helicopter-may be a good way to extend helicopter speed ranges. A stoppable tilt rotor that goes to higher speed on jet propulsion could be a follow on to the first tilt rotor. Besides X-Wing, several other means for stopping and stowing a helicopter rotor are possible. The list is long. Many of these schemes have been tried before, but the technology wasn't ready. In the next 20 years we can expect to see these reexamined in the light of the technology and the mission needs of the year 2000.

Summary

To recapitulate, it appears from Sikorsky Aircraft's vantage point that the rate of change of technology in the helicopter/VTOL field is still very high. The result is that helicopters, as we know them, will improve very significantly over today's products and that one or more of a list of advanced VTOL concepts will probably establish its mission in the family of aircraft types and go into wide-spread use. A major thrust of the improvement in helicopter/VTOL's will be that they become better neighbors - quieter, safer and smoother. The result of all this will be not just the expansion of the missions and uses we see today, but also the development of new uses we haven't even imagined yet.

We at Sikorsky are excited about the future and dedicated to helping to lead our industry to provide increased service and capability in the next century.

Mr. GLICKMAN. Thank you very much.

Mr. Schaufele.

Mr. SCHAUFELE. Mr. Chairman, I am pleased to participate with these distinguished members of the aeronautics community on these important issues that your subcommittee has raised.

Today I plan to give an overview of the tactical, strategic, and transport aircraft needs of the industry through the year 2000 and beyond, including some that may operate outside the atmosphere. I will speak of the new types of civil aircraft that might be expected in those years and the level of technology readiness that will be needed to make these new military and civil aircraft possible.

Foremost in the tactical arena is air superiority. A variety of potential conflict situations requires future aircraft with superior long-range weapons and fire control systems, standoff, long-distance engagements with high maneuverability to provide the capability for quick kills in close visual combat.

By the year 2000 the Soviet Union can be expected to have improved long-range aircraft with improve standoff weapons and cruise missiles. The defense of the continental United States require early detection by airborne warning and control systems and intercept by air superiority fighters, or perhaps long-range supersonic specialized interceptors.

Wing designs for these types of new interceptors are being based on the NASA-funded aerodynamics technology developed for the advanced supersonic transport model, represented on display in front of you today.

Fleet air defense could also require that the Navy conduct an outer air battle, protect the task force with long-range fighters employed in the combat air control, or deck-launched intercept modes.

The latter role might be filled by the post-1995 supersonic vertical/short takeoff and vertical landing aircraft that we are studying at the present time.

Strategic bomber needs at the end of this century will be fulfilled by the current B-1 and advanced technology bomber program. As means are developed for interception of the advanced technology bomber, however, additional countermeasures technology will need to be pursued.

Moving to future military transport requirements between now and the next century, reengining of the KC-135's and acquisition of KC-10's should well satisfy the Air Force's tanker needs. Condition of C-5's and C-17's of the military airlift fleets satisfy the requirements for long-range airlift of all sizes and weights of cargo and equipment.

Into the 21st century, the military will continue to require subsonic tankers and airlifters that are productive, fuel efficient, supportable, and long-lived, low-life cycle costs. Tactical airlifters will probably need to become less detectable than current designs in order to enhance survivability in the post-2000 environment.

For strategic airlift, unrefueled ranges of up to 10,000 miles will be required to minimize dependency on tankers. New configurations, including modified flying wing concepts, will likely emerge. There clearly will be a high interest in the greater efficiency of the propeller based on the high-speed propfan now under development by NASA. Contributing to the efficiency of these very long-range transports will be the use of lightweight structures and in all probability laminar flow control.

In the 21st century, control of space and effective use of space-based systems will be crucial in conflicts. We must be able to eliminate enemy offensive and surveillance systems in space and to defend our own systems against enemy antisatellite weapons.

Rapid access to and from space will be essential and will require more than follow-ons to the space shuttle. This will require an airplane that can achieve orbit. For example, for use in conflicts short of an all-out nuclear exchange, we see the role for a mach 12 strategic reconnaissance aircraft for daily operations on a routine basis by Air Force crews with conventional takeoffs and landings from existing air bases.

When needed, it could also be quickly mated to a short recoverable booster and launched into low Earth orbits, could maneuver in space, achieve multiple intercepts in orbit as high as 1,200 nautical miles, and reenter for powered atmospheric flight and landing.

Finally, the military will need relatively small numbers of a variety of special purpose vehicles for reconnaissance, command and control and other functions. Many of these vehicles will use available transport and combat airframes to carry high-technology specialized payload.

Now, turning to the civil aviation requirements for the next two decades and beyond, we see more than 4,000 new transport aircraft will be required to meet the projected world needs. The probable demand constitutes a $200 billion market opportunity for U.S. industry to continue civil aviation's role in providing the largest positive increment to the U.S. balance of trade of any manufacturing industry. The U.S. civil aviation industry also benefits this Nation through its enormous economic impact, providing jobs.

Further, we in the United States are now dependent for long-range travel on our excellent air network which accounts for some eight times as many passenger miles as its nearest rival among public transportation systems. Finally, the civil aircraft industry provides an important technology and facilities base for national defense mobilization support. But to continue these very substantial benefits, we must vigorously meet competition from European and Japanese industries that are strongly government supported as part of well-defined national economic strategies.

Kinds of aircraft needed to satisfy the near-term civil market are fuel-efficient derivatives of current aircraft plus a few new aircraft as we move into the 1990's. Our studies indicate that new aircraft in the 100- to 150-passenger category should be propfans, whose potential operating efficiency—efficiency is substantially better than derivative or new aircraft with the best turbofan engines.

In to the 21st century, demand for safe, comfortable, quite commercial transport aircraft will continue to grow with world populations. The market for very large, long-range aircraft—800 to 1,000 passengers— to operate between the largest population centers will develop and grow.

Demand for long-range travel should eventually make it possible to economically exploit the high productivity of supersonic flight. When this milestone is reached, supersonic transports for 350 or more passengers, like the model in front of you, could appear in the world airline fleet. The unusual geometry, both of the wing and the fuselage, of this model demonstrates the advanced aerodynamics technology developed in joint NASA industry programs over the past 10 years.

This technology is not waiting for economic viability of commercial supersonic transports for application. As I mentioned, it's already being applied to future military designs.

In the 1960's, we and NASA examined the requirements for hypersonic air transportation at speeds up to mach 6. While we foresaw its eventual technical feasibility, its economic viability was, and still is, uncertain. However, spinoffs from our development of hypersonic cruise and trans-atmospheric military vehicles discussed earlier may well make it possible for the eventual introduction of large hypersonic commercial transports. They would operate at altitudes that permit flight over populated areas without sonic booms, and the speeds would allow flights from Washington to Tokyo in 2 hours.

To meet these challenging high-performance goals for military aircraft and operating efficiency goals in civil transports, advanced technology must be developed and demonstrated before vehicle system development begins. Even if no immediate application is foreseen, it's essential that research and technology development be vigorously pursued by Federal agencies in conjunction with the private sector as national goals.

Maintaining a high level of technology readiness is crucial to future aircraft because of the many factors, such as financing, market demand and national strategies, that can affect the manner and timing of aircraft development.

I've outlined some of the technologies that are important to military and commercial transport aircraft and are crucial to attaining a desirable state of technology readiness.

For example, many technologies applicable to both military aircraft and to commercial transports are included in the ongoing programs initiated by NASA and the Congress some 8 years ago.

Among these efforts were the energy-efficient engine, engine component improvement programs. As a result of recent studies, many evolutionary ideas have been identified which, if pursued to fruition, would decrease fuel consumption of today's large turbofan engines by 25 to 30 percent.

However, after the energy-efficient engine program ends, there are no NASA technology programs for large turbofan propulsion systems until fiscal year 1987. The resulting 4-year gap will have a severe negative effect on our ability to maintain a competitive edge in the $70 billion large turbofan market predicted for the next decade.

Perhaps most significant for new aircraft application in the 1990's are NASA's advanced turboprop, or propfan, initiatives. Industry studies and studies in NASA's advanced program office show that 15 to 20 percent gains over the best turbofans are feasible if advanced propfans are brought to a satisfactory state of development. Most of the technology development is included in the NASA program.

However, the NASA initiatives should be strengthened in key areas, including noise and airframe integration. A planned contract for flight demonstration of a wing-mounted single-rotation propfan should be expanded to include fuselage-mounted conter-rotating pusher installations as well. Propfans may provide the largest single gain in operating efficiency of commercial transports that can be implemented before the next century.

After the year 2000, comparable benefits from laminar flow control technology may also be realized. However, first its reliable, economical applicability must be convincingly demonstrated. Therefore, the NASA LFC program should be continued to large-scale flight testing. LFC is a tremendous opportunity for future long endurance or long-range military aircraft, as well as long-range commercial transports.

An advanced metallic structures initiative should be added to the NASA program to help industry prepare to exploit the early benefit potential of aluminum-lithium alloys and to accelerate readiness to confidently and safely employ metal matrix composites for even greater potential benefit for the future.

Polymer-matrix composites applied to large wing and fuselage structures have about twice the weight-saving benefit potential of aluminum-lithium alloys. Moreover, composites or another form of bonded construction will be essential for laminar flow control wings, and polymer composite structures will be essential for future low-observable military aircraft. Therefore, NASA-funded development of this key technology should continue.

Finally, although avionics technology developments have already had a tremendous impact on both military and commercial aircraft system capabilities, projections of reduction in size and weight and improved capabilities are indeed astounding. Development of high resolution sensor systems, very high-speed integrated circuits, digital computers with bubble memory and digital communication links, laser gyros, the global positioning system, integrated displays will continue. We can envision aircraft that automatically take off, fly, carry out their mission, and land themselves. NASA- and DOD-funded efforts in this area must be ongoing.

For the 21st century, transatmospheric vehicles, operating at speeds up to mach 12 and at altitudes up to 1,200 nautical miles, space sensor and surveillance technology currently under development for satellite systems will be applicable and are necessary. Required weapons systems are typified by current maneuvering reentry vehicle and ballistic missile interceptor developments, and the metallic thermal protection system and high temperature structures technologies developed in the 1960's are still valid. These technologies would only have to be upgraded and adopted to the proposed combined hypersonic cruise aircraft and orbiter concept.

The key enabling technology for such flexible space missions is clearly propulsion. However, progress in development of combined cycle engines, such as the air turbo rocket engine, indicates that propulsion devices capable of performing these complex missions are within reach. Before this technology is available for military space missions, its development must be completed and valided. Required funding to mature this or other combined-cycle propulsion system technology for future missions should be provided. NASA and DOD contract efforts with industry are complemented by NASA's own in-house research.

However, the in-house element of NASA's aeronautics program, in particular is significantly weaker now than it was in the NACA's corresponding program before NASA was formed. A principal reason for concern over this comparison is recognition that DOD, as a developer and user of high-performance aircraft, tends to focus its research on the relative near term and is dependent on NASA for provision of a long lead, high-risk technology base.

Particularly conspicuous in this comparison is the lack of experimental aircraft in the combined DOD and NASA programs compared to the 1950's when much of our progress in advanced aircraft technology was pioneered with such program.

After this comparison of the past with today, and after evaluation of NASA's systems technology thrusts in aeronautics, we recommend that NASA's aeronautics effort be substantially increased. In particular, NASA's investment in future focused research and technology base efforts should be brought back to at least pre-NASA level. Especially needed is a major increase in effort in NASA's experimental aircraft research programs in cooperation with elements of the DOD and industry.

The complexity and variety of aeronautical systems and their underlying technology programs are so great that no single company can maintain all the test facilities needed for technology and aircraft development. Industry is dependent on NASA and DOD facilities even for development of proprietary technology and systems. Fortunately, existing and planned NASA and DOD facilities satisfy most needs at subsonic, transonic and supersonic speeds.

However, some additions are required to test at mach numbers from 6 to 20 at low angles of attack with reasonable flow quality to help develop some of the military aircraft we mentioned earlier. All but two of the existing wind tunnels with the acceptable capability up to mach 10 have either been scrapped or mothballed with resulting loss of experienced personnel. There are no such facilities capable of testing in the range from mach 10 to mach 20. Therefore, significant investment in new facilities is needed. I urge NASA and the DOD to define and support the specific additions that will meet these important requirements.

In summary, for national survival and safety as we approach and enter the 21st century, the United States must be ready with very advanced high-performance military aircraft for multiple operational roles within and beyond the atmosphere. If the aerospace industry is to maintain its important positive contributions to the Nation's trade balance, U.S. manufacturers must continue to produce the most advanced and efficient commercial transports in the world. Attainment of these goals will require a dual—evolutionary and revolutionary—approach to research and technology development. The need for low-risk, near-term programs that currently dominate NASA budgets is real and they should—and in all probability will—continue.

We in industry also strongly recommend substantial strengthening of joint NASA-DOD basic technology efforts, experimental aircraft programs aimed at 21st century systems that are high risk but have potential for high payoff. Toward these ends, we urge the technology development budgets, technology demonstration efforts and facility budgets be enhanced to the degree possible in the current environment.

We also recommend that facilities needed in the development of advanced hypersonic vehicles for the 21st century be defined and constructed as rapidly as we can.

We badly need to reenergize the innovative pioneering spirit that was the foundation of our current aeronautics industry if we are to insure our military and economic strength well into the next century.

Thank you.

[The prepared statement of Mr. Schaufele follows:]

STATEMENT BY
ROGER D. SCHAUFELE
VICE PRESIDENT, ENGINEERING
DOUGLAS AIRCRAFT COMPANY

BEFORE

COMMITTEE ON SCIENCE AND TECHNOLOGY
SUBCOMMITTEE ON TRANSPORTATION, AVIATION, AND MATERIALS
U.S. HOUSE OF REPRESENTATIVES
DECEMBER 5, 1983

Mr. Chairman and members of the Subcommittee, I am Roger D. Schaufele, Vice President of Engineering at Douglas Aircraft Company, a component of the McDonnell Douglas Corporation. Over the past six decades we at Douglas have built more than 43,000 military and civil aircraft.

The design of these aircraft and their capabilities have evolved in response to the world environment as the technology base has grown.

To understand what kinds of aircraft will be needed into the next century and the technology that will be required to make them possible, we have to picture the world as it will exist in those years.

Briefly, we feel there will be a continuation of world tensions that will require improved military capability on the part of the United States. We also believe civil air travel will grow by at least a factor of three, creating a need for more and more productive passenger aircraft.

Today, I plan to give an overview of the kinds of tactical, strategic, and transport aircraft that will be required by the military to the year 2000 and beyond and will operate within and beyond the atmosphere. I will speak of the new types of civil aircraft that might be expected in those years and the level of technology readiness that will be needed to make these new military and civil aircraft possible.

MILITARY AIRCRAFT

It is indeed important that Government and industry look ahead to military aeronautics technology needs and opportunities into the next century. Given the ever increasing strength and technical achievements of the Soviet Union, survival of freedom in this world depends in part on our definition and subsequent development of superior, affordable military aircraft systems for a number of roles.

The most probable applications of our military forces within the foreseeable future would occur in the tactical arena. Tactical aircraft warfare roles are many and varied. But common needs are speed and agility, low observability or deception, and firepower. In addition, these aircraft will need to be reliable, easily supported and, operable from short or damaged runways and dispersed, concealed locations. We need large numbers of these relatively sophisticated aircraft. Therefore, while I will focus today on required capabilities, we should recognize that technology must be focused to get both capability and affordability.

Foremost in the tactical arena is air superiority. The variety of potential conflict situations requires future aircraft with superior long-range weapons and fire control systems for stand-off, long-distance engagements and with high maneuverability to provide the capability for quick kills in close, visual combat.

Interdiction of enemy ground forces could also require aircraft with both stand-off and direct-attack firepower depending on the threat environment. Low observability is a desirable attribute for these penetration missions.

Close air support of our ground forces requires highly reactive aircraft capable of responding precisely to ground command and control while posessing improved defenses against surface-to-air weapons such as lasers in the late 1990's.

By the year 2000, the Soviet Union can be expected to have improved long-range aircraft with improved stand-off weapons and cruise missiles. Defense of the continental U.S. (CONUS) will require early detection by airborne warning and control systems (AWACS) and intercept by air superiority fighters or, perhaps, by long-range supersonic specialized interceptors like that shown in Figure 1. The wing design for this conceptual CONUS interceptor is based on NASA-funded aerodynamics technology developed by McDonnell Douglas for the advanced supersonic transport represented by the model on display before you today.

Fleet air defense could also require that the Navy conduct an "Outer-Air Battle" to protect the task force with long-range fighters employed in Combat Air Patrol or Deck-Launched Intercept modes. The latter role might be filled by the post-1995 supersonic Vertical/Short Takeoff and Vertical landing (V/STOVL) aircraft shown in Figure 2 that is proposed for development in a collaborative US/UK program. Involved in development would be the DoD, the Air Force, the Navy, and NASA, with various elements of the British aerospace establishment.

The needs for other Navy carrier-based aircraft required for Anti-Submarine Warfare, Carrier On-board delivery, and Airborne Early Warning are driven by the small number of these aircraft that can be assigned to a carrier. Therefore, a basic requirement is airframe design commonality to effectively perform all three of these missions.

Future Navy Long-Range Maritime Patrol Aircraft needs are another challenge. Ideally, one would like an aircraft capable of performing a submarine detection operation by flying to an area a thousand or so miles distant in minimum time and then staying on station for extended periods before returning home.

Strategic Bomber needs to the end of this century will be fulfilled by the current B-1 and Advanced Technology Bomber programs; as means are developed for interception of the Advanced Technology Bomber, however, additional counter-measures technology will need to be pursued.

Moving to future military transport requirements, between now and the next century, the re-engining of KC-135s and acquisition of KC-10s will well satisfy the Air Force's tanker needs. KC-10s will also alleviate some of its shortfall in long-range cargo capacity.

The addition of C-5s and C-17s to military airlift fleets will satisfy our remaining requirements for long-range airlift of all sizes and weights of cargo and equipment. The C-17 will satisfy the particular need for efficient direct delivery to battle areas (Figure 3), and can satisfy much of the Army's theatre airlift requirements.

Into the 21st century, the military will continue to require subsonic tankers and airlifters that are productive, fuel efficient, supportable, and long lived for low life cycle costs. Tactical airlifters, if they are to survive the battlefield arena, must be less detectable than current designs. Figure 4 shows a low-radar-signature propfan concept for a tactical transport and a lower-signature turbofan concept. Both must be capable of reliable, supportable operations from very short, unimproved fields.

For strategic airlift, unrefueled ranges of up to 10,000 miles will be required to minimize dependency on tankers. New configurations, like the modified flying wing concept of Figure 5, will likely emerge.

There clearly will be a return to the greater efficiency of the propeller, based on the high-speed propfan now under development in NASA's Aircraft Energy Efficiency Program (ACEE). Contributing to the efficiency of these very long-range transports will be the use of lightweight structures and probably laminar flow control (LFC).

In the 21st century, control of space and effective use of space-based systems will be crucial in conflicts. We must be able to eliminate enemy offensive and surveillance systems in space and to defend our own systems against enemy anti-satellite weapons. Rapid access to and from space will be essential and will require much more than follow-ons to the space shuttle. This will require an airplane that can achieve orbit.

For example, for use in conflicts short of an all-out nuclear exchange, Figure 6 is a concept of a Mach 12 Strategic Reconnaissance aircraft for daily operations on a routine basis by Air Force crews from airbases with conventional takeoffs and landings. When needed, it could also be quickly mated to a short, recoverable booster and launched into low earth orbits, could maneuver in space; achieve multiple intercepts in orbits as high as 1,200 nautical miles, and re-enter for powered atmospheric flight and landing.

Finally, the military will need relatively small numbers of a variety of special purpose vehicles for reconnaissance, command and control, and other functions. Many of these vehicles will use transport and combat airframes to carry high technology specialized payloads. For instance, Figure 7 shows the marriage of a Laser Weapon System with a military tanker/transport of today, the KC-10.

Special aircraft designed for very high altitude/long-endurance missions with ability to survive in a post nuclear exchange environment will also be required. One potential Post-Attack Reconnaissance/Strike (PARS) aircraft concept is shown in Figure 8. It also employs much of the NASA-funded aerodynamics technology derived by McDonnell Douglas in our commercial advanced supersonic transport studies.

CIVIL AIRCRAFT

Now, turning to the civil aviation requirements of the next two decades and beyond, more than 4,000 new transport aircraft will be required to meet the projected world needs. The probable demand constitutes a $200B market opportunity for U.S. industry to continue civil aviation's role in providing the largest positive increment to the U.S. balance of trade of any manufacturing industry. The U.S. civil aviation industry also benefits this nation through its enormous economic impact in providing jobs.

Further, we in the U.S. are now dependent for long-range travel on our excellent airline network which accounts for some eight times as many passenger miles as its nearest rival among public transportation systems. Finally, the civil aircraft industry develops technology useful in military aircraft and provides an important base for national defense mobilization support. But, to continue these very substantial benefits, we must vigorously meet competition from foreign industries that are strongly government-supported as part of well defined national economic strategies.

Kinds of aircraft needed to satisfy the near-term civil market are fuel efficient derivatives of current aircraft plus one or two new aircraft as we move into the 1990's. Our studies indicate that new aircraft in the 100-to-150 passenger category should be propfans, whose potential operating efficiency is substantially better than derivative or new aircraft with the best turbofan engines (Figure 9).

Into the 21st century, demand for safe, comfortable, quiet commercial transport aircraft will continue to grow with world populations. A market for very large, long-range aircraft (800-1000 passengers) to operate between the largest population centers will develop and grow.

Dedicated and convertible cargo versions of these large aircraft also will be in demand. Escalating costs and eventual shortages of petroleum-based fuels will increase the importance of operational efficiency and create the need for alternate fuels.

Demand for long-range travel should eventually make it possible to economically exploit the high productivity of supersonic flight. When this milestone is reached, supersonic transports, like the model before you, could appear in the world's airline fleets. The unusual geometry, both of the wing and fuselage, of this model demonstrates the advanced aerodynamics technology developed by McDonnell Douglas in NASA-funded programs over the past ten years.

As I have already noted, this technology is not waiting for economic viability of commercial supersonic transports for application. It is already being applied in advanced fighter aircraft designs such as the long-range supersonic interceptor of Figure 1. It may also be used in other military aircraft such as the PARS vehicle of Figure 8.

In the 1960's we and NASA examined the requirements for hypersonic air transportation at speeds up to Mach 6 (Figure 10). While we foresaw its technical feasibility, its economic viability was, and still is, uncertain. However, spin-offs from our development of hypersonic cruise and trans-atmospheric military vehicles (Figure 6) may well make possible the eventual introduction of large hypersonic commercial transports. They would operate at altitudes that will permit flight over populated areas without sonic booms. Speeds will permit flights from Washington to Tokyo in two hours.

TECHNOLOGY REQUIREMENTS

To meet these challenging high performance goals for military aircraft and operating efficiency goals in civil transports, advanced technology must be developed and demonstrated before vehicle system development begins. Even if no immediate application is foreseen, it is essential that research and technology development be vigorously pursued by Federal agencies, in conjunction with the private sector, as national goals

This on-going approach to research and technology development, properly combined with appropriate technology demonstration, will result in technology readiness when applications need to be implemented in U.S. military or civil arenas.

Maintaining a high level of technology readiness is crucial to future aircraft because of the many factors that can affect the manner and timing of aircraft development.

For example, the timing of system development needs may be dictated by military or competitive-commercial developments in other nations; it could be affected by availability of financial resources, as well as national or business strategies. We've outlined some technologies that are important to military and commercial transport aircraft and are crucial to attaining a desirable state of technology readiness.

For example, many technologies applicable to both military aircraft and to commercial transports are included in the on-going ACEE program initiated some eight years ago by Congress and NASA.

Among the ACEE efforts were the Energy Efficient Engine (EEE) and Engine Component Improvement Programs. As a result of recent studies, many evolutionary ideas have been identified which, if pursued to fruition, would decrease fuel consumption of today's large turbofan engines by 24 to 30 percent.

However, after the EEE program ends, there are no NASA technology programs for large turbofan propulsion systems until FY 1987. The resulting four-year gap will have a severe negative effect on our ability to maintain a competitive edge in the $70 billion large turbofan market predicted for the next decade.

Needed research and technology development programs include development of new metal, composite, and ceramic materials for high temperature, high pressure cores. Also needed are development of aerodynamic methods for optimizing engine and related airframe geometries, and development of integrated digital propulsion and aircraft controls to optimize aircraft performance and response.

Perhaps most significant for new aircraft application in the 1990's are NASA's advanced turboprop, or propfan, initiatives. Industry studies and studies in NASA's Advanced Turboprop Program show that 15 to 20 percent gains over the best turbofans are feasible if advanced propellers--or "propfans"--are brought to a satisfactory state of development. Most of the necessary technology development is included in the NASA Program. However, the NASA initiatives should be strengthened in key areas, including noise and airframe integration. A planned contract for flight demonstration of a wing-mounted single-rotation propfan should be expanded to include fuselage-mounted counter-rotating pusher installations. Propfans will provide the largest single gain in operating efficiency of commercial transports that can be expected before the next century.

After the year 2000, comparable benefits from laminar flow control (LFC) technology may be realized. However, first its reliable, economical applicability must be convincingly demonstrated. Thus, the NASA LFC Program should be continued to large scale flight testing. LFC is a must for future long endurance or long-range military aircraft, as well as long-range commercial transports.

An "Advanced Metallic Structures" initiative should be added to the NASA program to help industry prepare to exploit the early benefit potential of aluminum-lithium alloys and to accelerate readiness to confidently and safely employ metal matrix composites for even greater potential benefit in the future.

Polymer-matrix composites applied to large wing and fuselage structures have about twice the weight-saving benefit potential of aluminum-lithium alloys. Moreover, composites or another form of bonded construction will be essential for LFC wings and polymer composite structures will be essential for future low-observable military aircraft. Therefore, NASA-funded development of this technology should continue.

NASA should also continue its cooperative efforts with industry to identify improved aerodynamic configurations, develop the technical data base, and introduce improved design methods. This includes forward swept wings and canards for future aircraft including LFC and other transports.

Finally, although avionics technology has already had a tremendous impact on both military and commercial aircraft system capabilities, projections of reduction in size and weight and improved capabilities are astounding. With continued development in high resolution sensor systems, Very High Speed Integrated Circuits, digital computers with bubble memory and digital communication links, laser gyros, the global positioning system, and integrated displays, we can envision aircraft that automatically takeoff, fly, carry out their mission, and land themselves. NASA and DoD-funded efforts in this area must be ongoing.

For 21st century trans-atmospheric vehicles, operating at speeds up to Mach 12 and altitudes up to 1,200 nautical miles, space sensor and surveillance technology currently under development for satellite systems will be applicable and necessary. Required weapons systems are typified by current Maneuvering Re-entry Vehicle (MaRV) and Ballistic Missile Interceptor (BMI) developments, and the metallic thermal protection system and high temperature structures technologies developed in the 1960's are still valid. These technologies would only have to be upgraded and adapted to the proposed combined hypersonic-cruise-aircraft and orbiter.

The key enabling technology for such flexible space missions is clearly propulsion. However, progress in development of combined cycle engines, such as the Air Turbo-Rocket (ATR) engine, indicates that propulsion devices capable of performing these complex missions are within reach. Before this technology is available for military space missions, its development must be completed and validated. Required funding to mature the technology for this and other combined-cycle propulsion systems for future space missions should be provided.NASA and DoD contract efforts with industry are complemented by a large NASA research and technology development effort in-house and through grants. However, this element of NASA's aeronautics program, in particular, is significantly weaker now than was NACA's corresponding program before NASA was formed. A principal reason for concern over this comparison is recognition that DoD, as a developer and user of high performance aircraft, tends to focus its research on the relative near-term and is dependent on NASA for provision of a long lead, high-risk technology base. Particularly conspicuous in this comparison is the lack of experimental aircraft in the combined DoD and NASA programs compared to the 1950's when much of our progress in advanced military aircraft was pioneered with such experimental aircraft.

Thus, after evaluation of NASA's systems-technology thrusts in aeronautics and this comparison of the past with today, we recommend that NASA's aeronautics budget be substantially increased. In particular, NASA's investment in future-focused Research and Technology Base efforts should be brought back at least to the pre-NASA NACA level, when aeronautics manpower was 5,700 compared to about 3,800 today. Especially needed is a major increase in NASA's experimental aircraft research programs in cooperation with elements of the Department of Defense.

FOREIGN INVESTMENT

According to the recent study of Aeronautical Research and Technology Policy, led by the Office of Science and Technology Policy, Soviet investment in aeronautics technology dwarfs ours. Some nine well-staffed "research institutes" conduct aeronautics research in the Soviet Union across the total spectrum of disciplines. Support, as needed, comes from Soviet Accademy of Science Institutes. In addition, eight "design bureaus" develop new and improved military and civil aircraft systems in close coordination with certain of the research institutes.

Other foreign government total support for commercial transport aircraft development is difficult to measure with exactness, but also is substantially greater than ours. The intense pressure to provide early and adequate return on the enormous investment required to develop new aircraft programs, as is the case with private U.S. companies, is not the driving force behind foreign aeronautical investment. Instead, the most critical factors are to improve the technological base of the nation and add significant employment benefits.

Foreign governments consider their aeronautical technology and production capability as national resources, to be enhanced with substantial outlays from the public treasuries. Their resolve to sustain a national aviation industry can best be exemplified with Airbus Industrie. A massive R&D investment, several years in advance of any possible break-even point, has not diminished the determination of the participating governments. Estimates indicate that as of the end of this year Airbus Induustrie is between $5 billion and $8 billion in the red, with R&D a big part of that total.

R&D FACILITIES

The complexity and variety of aeronautical systems and their underlying technology programs are so great that no single company can maintain all the test facilities it needs for technology and aircraft development. Industry is dependent on NASA and DoD facilities even for development of proprietary technology and systems. Fortunately, existing and planned NASA and DoD facilities satisfy most industry and government testing needs at subsonic, transonic, and supersonic speeds. For example, the supersonic V/STOVL fighter configuration shown in Figure 2 will be extensively tested in 1984 in three NASA Ames wind tunnels.

The National Transonic Facility (NTF), to be dedicated by Vice President Bush tomorrow at NASA's Langley Research Center, will add a new dimension to our national aerodynamic test capability. Its operation at cryogenic temperatures will permit attainment, under controlled wind tunnel conditions on small models, of full-scale values of the key aerodynamic parameter called Reynolds number. Our current inability to achieve such values before flight testing of prototype vehicles has been responsible for many mistakes that were costly in terms of design changes and lost performance. The Congress and NASA are to be congratulated for foreseeing the need and for providing this important facility.

The NTF will not replace low-Reynolds-number facilities and the demand for testing in existing low-Reynolds-number facilities will remain high. Test values from these facilities will be enhanced by NTF results. NASA and DoD low-Reynolds-number facilities should continue to be operated and maintained and, where their productivity can be raised, they should be enhanced by upgraded data acquisition systems or other improvements. This will require a continuing investment in government aeronautical R&D facilities, even without the addition of new ones.

But, some additions are required. These relate to development of hypersonic cruise and trans-atmospheric vehicles I have already mentioned. Such developments require the ability to test at Mach numbers from 6 to 20 at low angles of attack with reasonable flow quality. Existing tunnels with such capability, that remain in operation, are the Mach 7 Eight-Foot High Temperature Structures Tunnel at NASA Langley and the Mach 8-10 Tunnel B at the Arnold Engineering Development Center, Tullahoma, Tennessee. All higher-Mach-number facilities that provided acceptable flow quality have now been mothballed or scrapped; moreover, the unique skills for their operation and maintenance have been dispersed or lost through retirements. Thus, there are indeed apparent needs for significant investment in new facilities and I urge NASA and the DoD to define and advocate the specific additions that will meet these important future requirements.

AERONAUTICS POLICY AND TECHNOLOGY TRANSFER

We in industry generally agree with the comprehensive statement of aeronautical research and technology policy that was defined last year by U.S. Government personnel under the leadership of the OSTP. We also believe NASA and DoD technology goals are appropriate and consistent with the OSTP policy. And, although I have already noted some deficiencies in funding levels, we generally see short-term consistency between these goals and specific on-going and planned research and technology programs. The need for the low-risk, near-term programs that currently dominate NASA and DoD budgets is real and they should, and will, endure.

But, we also badly need to re-energize the innovative, pioneering spirit that was the foundation of our current aeronautics industry if we are to ensure our military and economic strength well into the next century. Our largest concern is the relative lack of long-term, high-risk research and technology in both NASA and DoD programs. In particular, we cite the absence of experimental aircraft in both agencies' programs. In general, we would say the Administration's aeronautical policy is not yet being implemented in the needed aggressive and balanced manner.

We agree with the findings and recommendations of the OSTP aeronautics and technology policy that viable mechanisms must be found for effective control of technology transfer and for U.S. exploitation of foreign aeronautical R&D. However, technology cannot be protected completely or indefinitely. Nor can we depend principally on acquisition or exploitation of others' technologies. The only way to assure superior qualities in our aeronautical products is to stay ahead of our adversaries and the competition in pushing the boundaries of technology outward.

Moreover, today's economic realities, including high interest rates, U.S. deregulation, and markets limited by world recession, are driving U.S. industry toward international cooperative programs for access to funds and markets. Such cooperative programs clearly promote the exchange of technology, but have significant benefits for the U.S. They have been known to forestall development of competing systems by foreign consortia and to protect as many as four jobs here for each one created overseas.

SUMMARY

In summary, for national survival and safety as we approach and enter the 21st century, the U.S. must be ready with very advanced, high performance military aircraft for multiple operational roles within and beyond the atmosphere. And, if the aerospace industry is to maintain its important positive contributions to the nation's trade balance, U.S. manufacturers must continue to produce the most advanced and efficient commercial transports in the world. Attainment of these goals will require a dual--evolutionary and revolutionary--approach to research and technology development. Both approaches require aggressive, coordinated U.S. Government support with the efforts distributed according to the OSTP Aeronautical Research and Technology Policy.

Clearly, ongoing NASA and DoD evolutionary systems technology efforts should be continued and should be strengthened where projected high payoffs and urgent needs dictate. But, especially, we in industry strongly recommend substantial strengthening of joint NASA/DoD basic, generic technology efforts and experimental aircraft programs aimed at 21st century systems that are high risk, but have potential for high payoff. Toward these ends we recommend research and technology development budgets and technology demonstration budgets be substantially increased. We also recommend that facilities needed in development of advanced hypersonic vehicles for the 21st century be defined and constructed as rapidly as possible.

FIGURE 1 - USAF ADVANCED SUPERSONIC INTERCEPTOR

FIGURE-2 - US/UK SUPERSONIC V/STOVL FIGHTER

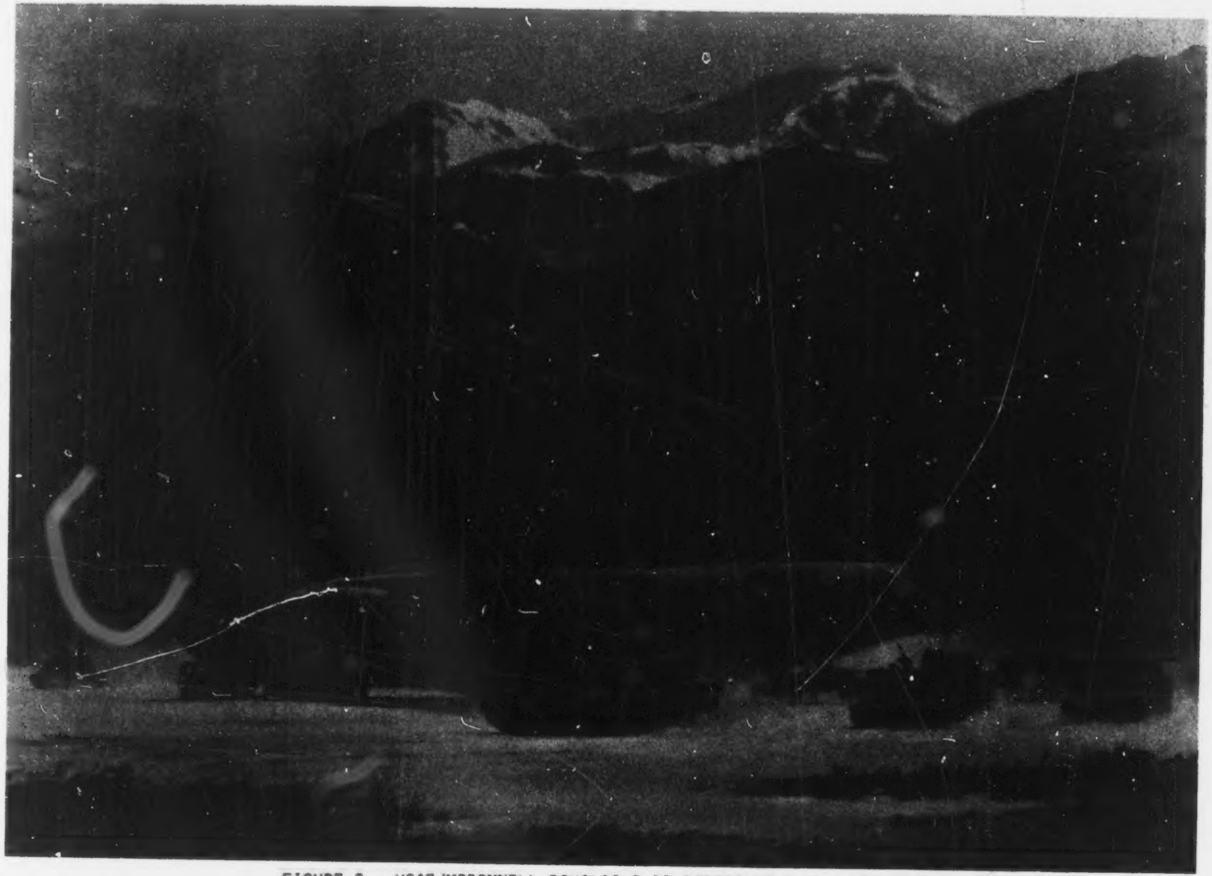

FIGURE 3 - USAF/MCDONNELL DOUGLAS C-17 DIRECT-DELIVERY AIRLIFTER

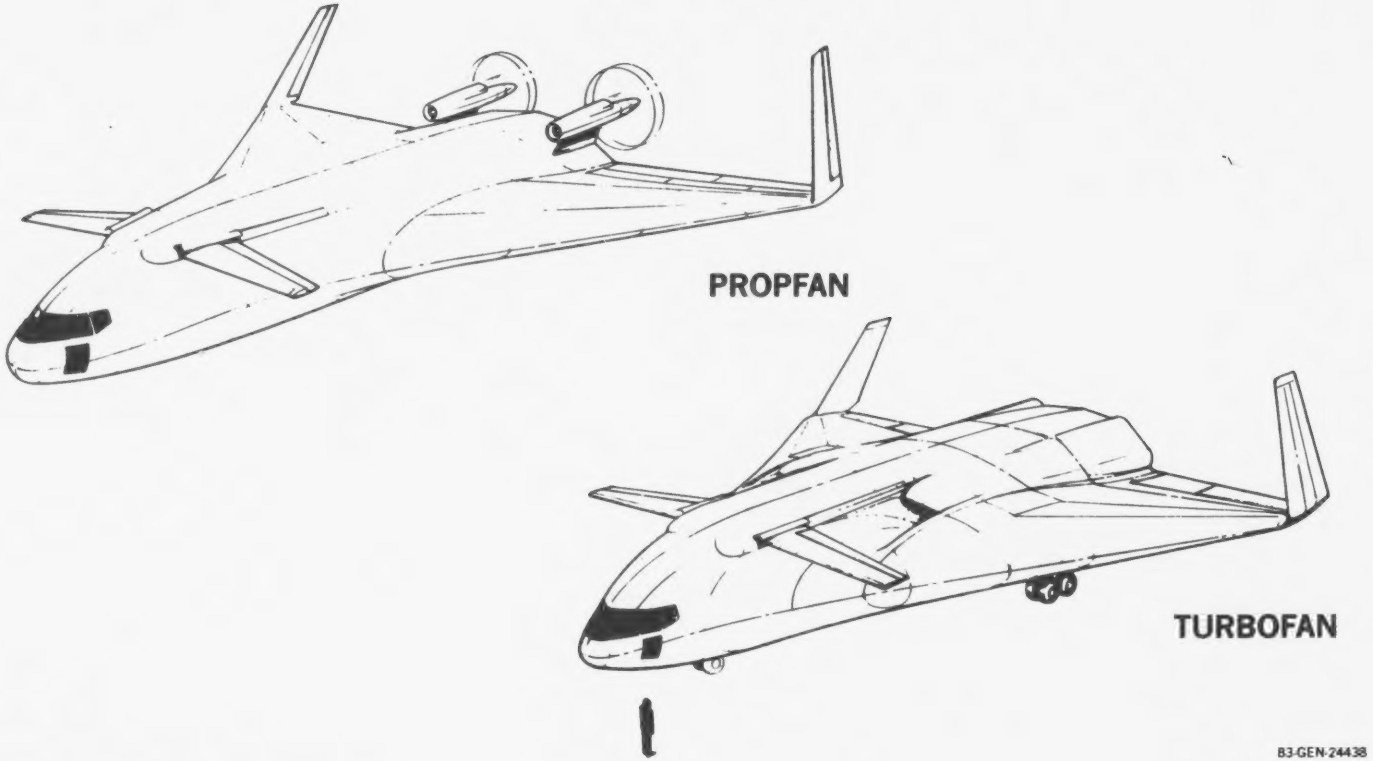
PROPFAN
TURBOFAN
83-GEN-24438

FIGURE 4. LOW-SIGNATURE ASSAULT TRANSPORT CONFIGURATIONS

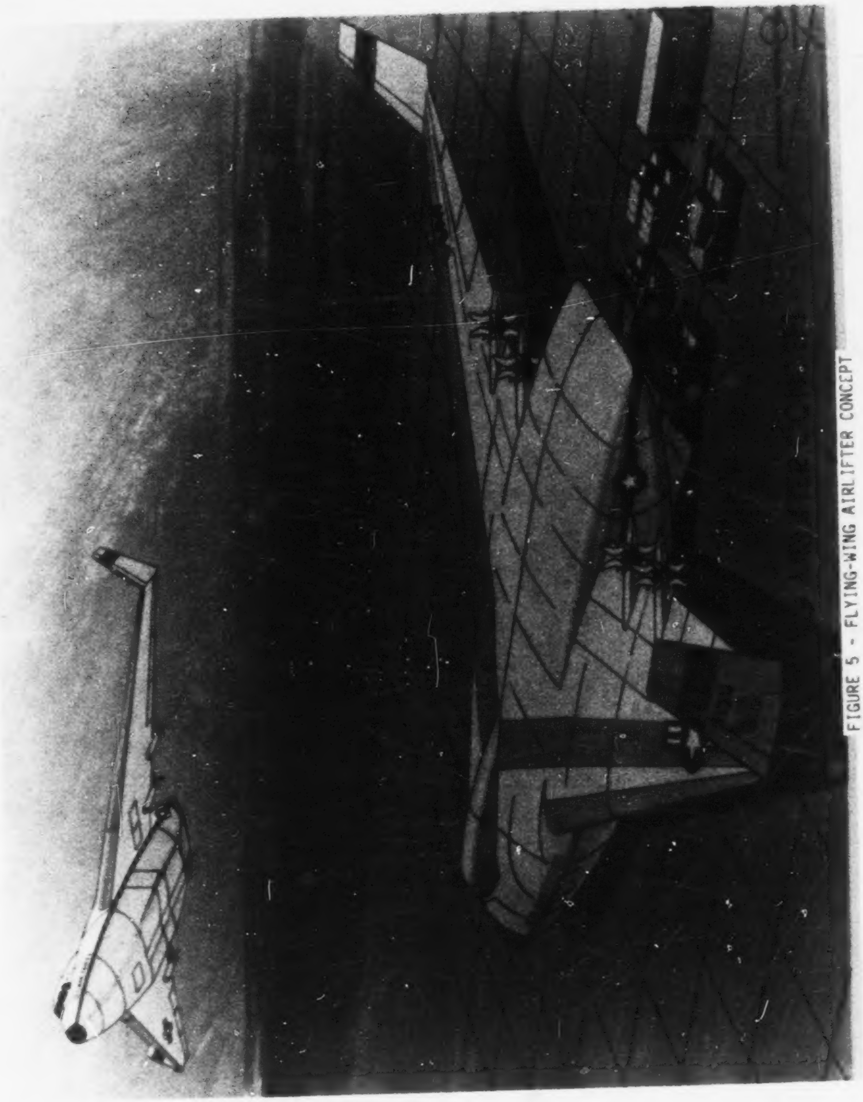

FIGURE 5 - FLYING-WING AIRLIFTER CONCEPT

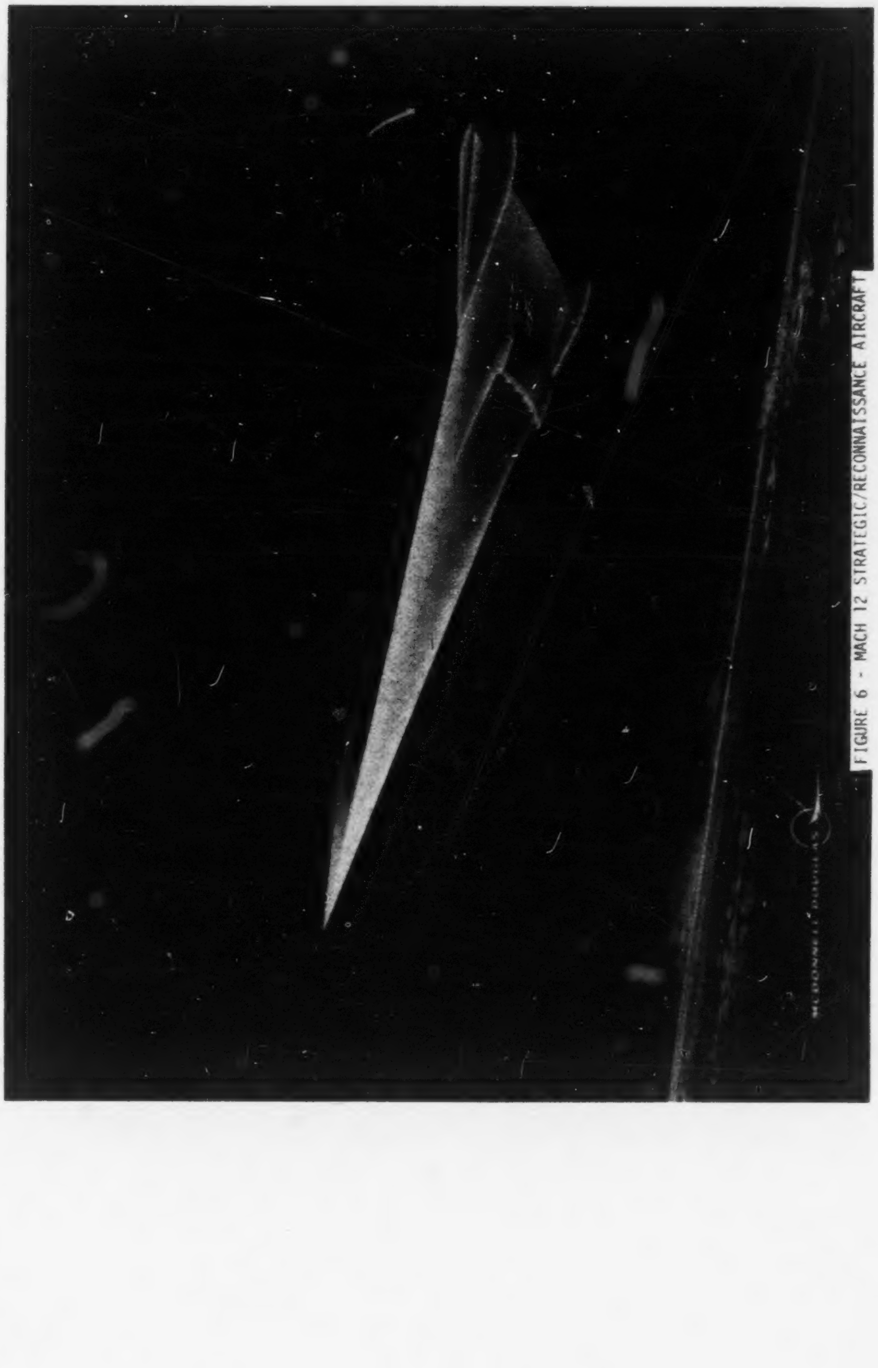

FIGURE 6 - MACH 12 STRATEGIC/RECONNAISSANCE AIRCRAFT

FIGURE 7 - AIRBORNE LASER WEAPONS SYSTEM

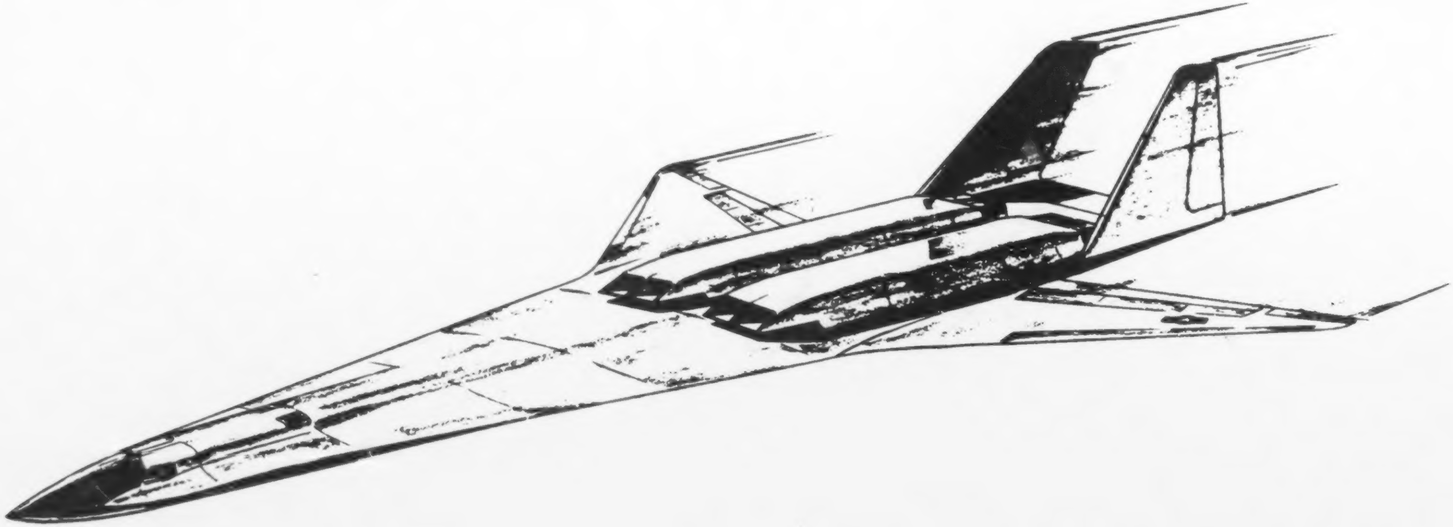

FIGURE 8. POST-ATTACK RECONNAISSANCE/STRIKE AIRCRAFT

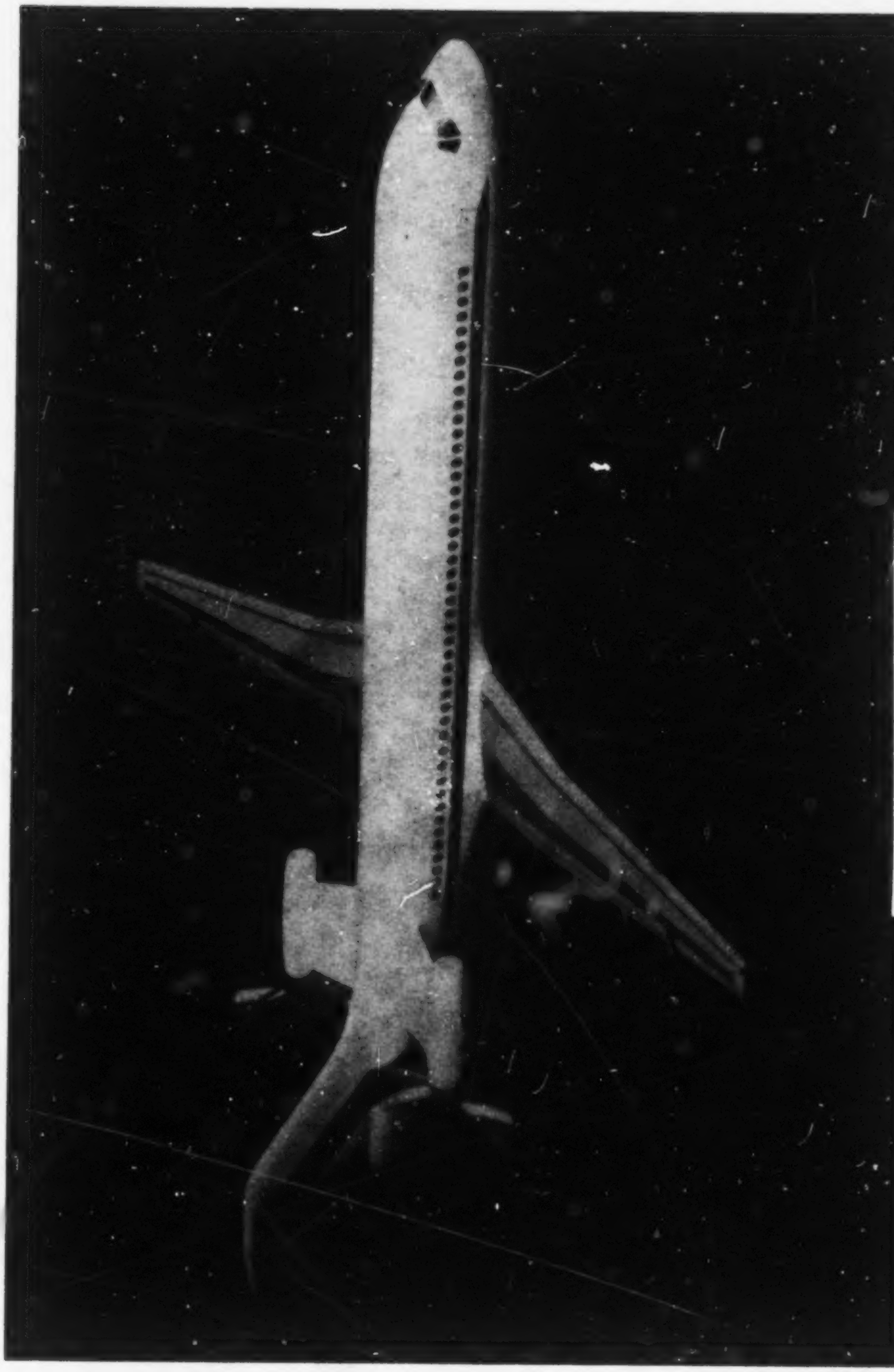

FIGURE 9 - PROPFAN TRANSPORT - 1992

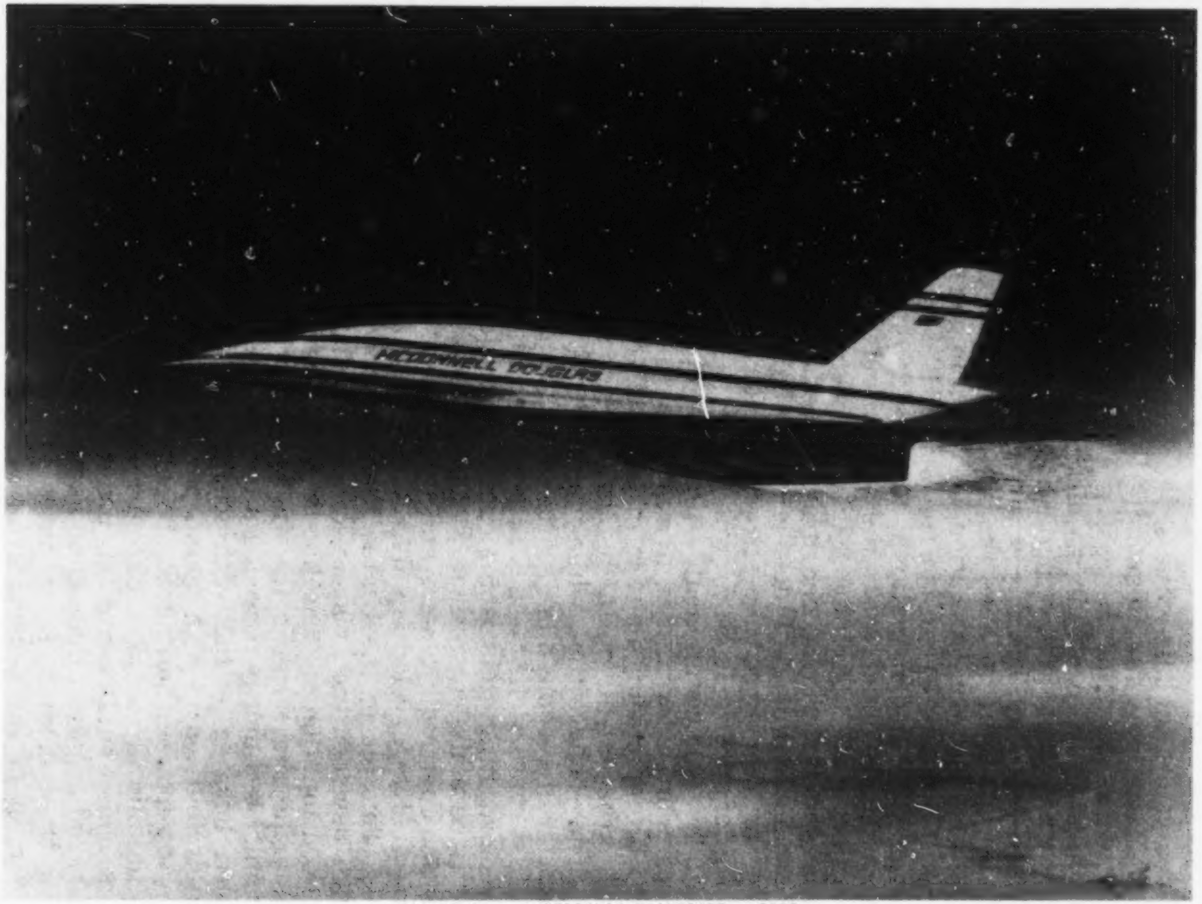
MCDONNELL DOUGLAS

FIGURE 10 - HYPERSONIC TRANSPORT - 2000+

Mr. **Glickman**. Thank you for a very thorough statement. We appreciate it.

Chet, you're the last witness.

Mr. **Rambleske**. Mr. Chairman——

Mr. **Glickman**. Not the least and, given the fact that you employ several thousand people in my district, you may be the most important witness that we have here today.

Mr. **Rambleske**. Thank you, sir.

It is a pleasure to have the opportunity to address such an esteemed audience on our national position in general aviation.

Approximately 1 year ago, the White House Office of Science and Technology issued six national goals for aeronautics. Three of these are extremely important to the general aviation industry. One was to maintain an environment in which civil aviation and manufacturing can flourish; second insure the industry has access to and can compete fairly in domestic and international market; and third, insure a timely and proven technology base to support development of superior U.S. aircraft.

The last policy statement, a timely and proven technology base is most important—and it is my reason for being here this morning. I want to express my opinion of some of those areas in which we need to concentrate our technology development.

I firmly believe that, while fuel is plentiful and relatively cheap now, it will become more scarce and expensive as we proceed into the 21st century. In the past, the United States has lead the world in reciprocating and turbine engine technology. But aviation gasoline is becoming increasingly scarce, comprising 5 percent of the aviation fuel requirement, and turbines still use 40 to 60 percent more fuel to develop equal power than that of reciprocating engines. This places the United States at the mercy of any country which develops the aviation kerosene-fueled engines with specific fuel consumption of a gasoline or diesel engine.

Imagine the scenario in which some other country develops a ceramic technology based rotary engine, turbocharged, liquid-cooled, burning jet fuel with specific fuel consumption of approximately four-tenths of a pound per horsepower, and weighing less per horsepower than our best reciprocating engines of today, and costing midway between our current reciprocating and turbine engines. This would destroy our present engine industry and, through restricted export of the engine and rigorous development of aircraft using these engines, the country so swept could completely dominate most of the general aviation market throughout the world, except possibly the upper end of the marketplace.

Now, NASA's been funding some studies in this area. But I feel that funding has been inadequate to pursue the national goals stated. We strongly recommend that this program be getting a higher priority in this list of priorities.

Speaking generally of budgets, the total NASA aeronautics budget is only 80 percent of NASA's total budget, which I feel is totally inadequate percentage when considering the importance of the aeronautics business to our national policy.

That segment known as general aviation suffers even more. Total R&D expenditures by NASA for the general aviation segment were less than $10 million last year, of which, at least was spent for administrative purposes.

We recommend that monies be reproportioned, not necessarily increasing total NASA budget. We feel that money is needed to be spread to individual and small corporations with the known capabilities and creative ideas.

The following areas are areas which we feel should be pursued in future R&D expenditures. Avgas, first of all, is alternate fuel. Avgas will continue to be a smaller and smaller percentage of our refinery output. Therefore, it will become more expensive relative to other fuels, or even unavailable in some parts of the world.

To counter this problem, research is required in both the airframe and engine areas to make available power packages that are competitive with existing technology, but able to use fuels that will be more widely available in the next century.

On the subject of engines, significant amounts of research are being conducted by industry and Government on large turboengines, but virtually nothing is being expended on small turbo or reciprocating power plants for future aviation use.

Major improvements in specific weight and fuel usage are potentially available. These improvements would permit more economic performance. Typically, 60 to 75 percent of the energy available in fuel goes overboard in the form of exhaust today. Efforts in this area might prove very, very fruitful.

Another subject that we feel needs concentration, advanced aerodynamics. Continuing research needs to be done on the potential benefits and pitfalls of advanced aerodynamic configuration, including active flight control systems in small general aviation type aircraft. The benefits and pitfalls need to be identified in terms of a complete design process.

For example, active control system may save weight by reducing structural weight, but redundancies could soon result in a heavier overall redesign. Numerical aerodynamic methods need to be continued as—and developed into practical design tools.

Further work needs to be done in navigation systems, cost reduction for affordable use of such systems by general aviation, which would provide more accuracy and more ease of use, improved area in navigation to reduce congregation over navigation facilities.

Another area where we feel significant progress would be forthcoming if proper research is expended, and that is in computer-aided design and manufacturing. Significant steps have been taken in the areas of computer-aided design, but the step to flexible computer-aided manufacturing is not yet available except in limited piece parts machining. Large amounts of research in the area of robotics to apply these advances to the limited production runs—typical of the manufacturing done in the aerospace industry.

ADVANCED MATERIALS

Continued research is required in the area of manufacturing, repair and aging of advance composite materials. Advances in conventional materials, such as new aluminium and titanium alloys, also need to be validated and brought to the point of practical application. Advanced materials can be applied not only to general aviation, but to military and the airline area.

Composites have enjoyed considerable R&D effort by both the military and some of the large civil aircraft manufacturing companies. However, little, if any, R&D money has been funneled to the general aviation industry. One U.S. manufacturer has even turned to foreign capital to pursue its efforts in this area. Those areas dealing with composites which have been underway today refer and relate to large aircraft. They are not applicable to our type of airplanes.

Beech Aircraft has recently introduced its Starship I, a unique advanced aeronautical design which will use an airframe made completely of composites. We chose composites because of its heralded light weight to strength ratio.

However, in our work so far, we have been appalled that, after 20 to 25 years of research, and no standards have been developed to date. While we realize that the industry is moving rapidly, there is no basic set of data that anyone can turn to. Each manufacturer wanting to use composites is faced with developing and certifying his own new material base. This single factor could be the greatest obstacle we have to overcome in developing our Starship, but we will do so.

It would be beneficial to the entire general aviation industry if NASA would provide studies—specific studies—in the following areas. One, NASA should have a more detailed look at composite structures in their true design values for aircraft weighing between 10,000 and 30,000 pounds, with cost comparisons with similar metallic aircraft and true weight comparisons.

Second, produce a manual for composite materials similar to the existing Mill Handbook V for metallic materials and elements for aerospace vehicle structures.

Three, develop modeling data for structural analysis of unsymmetrical aircraft configuration at low transonic speeds.

Four, flow fields around different aircraft configurations need attention. On newer non—nonconventional aircraft configurations, such as our Starship I, oblique wings, forward-swept wings, various other unique configurations, empirical data and analytical methods on what the local flow field—downwash, upwash, sidewash—are next to the components of the aircraft is vitally important. This information is needed to properly size lifting and control surfaces, such as wings, forward wings, canard, vertical fins, tipsales, and so on, and so forth.

Five, investigate aircraft configurations for up to 40,000 pounds and transonic speeds up to 1.2 mach numbers.

Six, investigate energy-efficient aircraft in the general aviation arena that is 25,000 pounds or less.

Seven, develop better airfoils—or at least try to—that are good for low speed as well as transonic speeds up to 1.2 mach number. Remember that high-speed aircraft are not very useful if we cannot maintain good safe flight in the landing approach configuration and in the terminal area and still maintain the use of our existing airports.

Another subject which we are very interested, and that is certification of aircraft. We must do something to reduce the development and certification time required for our products.

Beech recently certified the model 1900 commuter airliner, a 16,000 pound, 19-place, 300-mile-an-hour local service airliner. This airplane drew heavily on the technical information of our model 200 and incorporated very little new technology, yet required 4 years to develop and certify. This is 15 months longer than previous certification programs.

The efforts in these areas have gone unchecked partly due to the new rules set up to supposedly enhance development of this type of aircraft. But the new rules open the door for new interpretations and considerably more participation throughout the certification process. General aviation aircraft were subject to reevaluation and reinterpretation. We need a review and possible change to the Administrative Procedures Act which establishes how we must act relative to the timely and necessary changes in our regulation. The procedure takes all too much time.

Government research in the recent past has tended to center on esoteric pure research areas, with practical application of this research left to the commercial industry. In theory, this is a proper division of Government-funded research, but frequently fails to carry the research to the point of proof of concept on any practical level. Therefore, the application of new concept falls entirely on the shoulders of industry with very little useful assistance from the Government.

We, as a nation, need to look to the manner in which we did research in the past and the manner in which other nations are targeting their research toward practical application of new concepts and ideas. Much of the research done in Japan today is targeted at bringing new concepts to the point of commercial application in general aviation. These are not simple applications of existing technology but aggressive pushes of the state of the art that are carried through to a useful conclusion.

This goal-oriented research was what allowed this country to move into space and become leaders in the area of microelectronics and the like. The lessons of this type of research appear to be forgotten in the light of today's governmental research program.

One additional point I wish to add in speaking of this Starship I program. We initiated a new program for an entirely new aircraft. The aircraft will have all of the latest state-of-the-art capability built into it. It will have advanced avionics; it will have an advanced electrical system; it will be made completely of composites. We are proceeding on the basis that we will have an airplane ready for the marketplace in slightly over 2 years at a cost to us well in excess of $100 million.

Thank you, sir.

Mr. Glickman. Thank you, Chet. I appreciate your running through the litany of specific recommendations for NASA to be pursuing, such as the composites manual and other kinds of things that you will need to do.

Let me just ask Roger this question. During the energy crisis of the late seventies, as well as the early seventies, aircraft manufacturers became very pessimistic about the possibility of an economic supersonic transport. As you heard from a little bit of the colloquy between Mr. Harkin and Chuck Yeager, that it may have been better that we didn't build it then. However, energy prices have stabilized and technology has moved forward.

Have you done any studies on SST economics since, oh, 1976, 1977? I mean, have you done any modern state-of-the-art statistical studies of the costs of operating a new technology SST?

Mr. SCHAUFELE. We have continued to study the economics of the SST in the light of our continuing technology work, and I think at the moment it still doesn't look too promising for near-term application. But as we continue to make strides in all of the technology areas, a lot of the cost elements in the supersonic transport will improve.

For example, in the time we have been working on the aerodynamic characteristics, we have made an almost 50-percent improvement in the cruise lift-to-drag ratio. That type of thing, combined with improvements in the structural weight ratio and the propulsion system we believe will lead to better economics that will allow a future viable commercial SST.

Mr. GLICKMAN. And while your company doesn't build the B-1, do you subscribe to Dr. Mark's thesis that the B-1B might be a very effective research airplane for advanced supersonic transport in terms of the practical aspects of flying such an aircraft?

Mr. SCHAUFELE. I would agree with Dr. Mark, that a lot of valuable experience will be obtained in the operation of the B-1B, that would have applicability to the commercial supersonic transport.

However, I'm a little pessimistic about how much good economic data on the overall maintenance cost and some of the other aspects that he mentioned will really be able to help in the studies on the overall economic picture. I think the technical experience and operation will be very useful. I think that the dominant economics will come out of the technology work that's done, plus the analyses that are made prior to committing to production on the overall economic aspects of the program.

Mr. GLICKMAN. Dr. Jenney, do you see a need for very large, heavy-lift helicopters and do you think that NASA ought to be working on this particular design, at least from an R&D point of view?

Dr. JENNEY. The latter part of the question is easy. I think the R&D end of it certainly should go forward. The other part you know is a loaded question, that there are very large loads that need to be moved that need that sort of lift capability, but they don't come along very often. So the economics, General Yeager's point, still has to work itself out. But we certainly ought to get the research done so that we know how to build such a thing when the arithmetic is done, to show the mission desirability.

Mr. GLICKMAN. Chet, do you think that any of the propfan work, the advanced propeller work, will be useful to general aviation?

Mr. REMBLESKE. Not in the sense that it's being conducted now. We have suggested and are trying to convince various people that propfan work needs to be extended down to the general aviation area—in other words, down to probably 1,800, maybe 1,500 horsepower type engines.

We find no interest in the industry today to do that on their own. It is a very expensive program to do. We feel there will be some information gained, but the proof of the pudding and the real applicability of that type of prop installation in our type of aircraft would come through a program to run a similar program to what NASA is now running on large propfans to our size aircraft.

Mr. GLICKMAN. Let me ask you a question to follow up on Mr. Carney's comments before, when he was asking why have the foreign companies like DeHavilland and Shorts and Saab been able to leapfrog—I think I'm using his words correctly—technology, where American general and commuter manufacturers haven't been able to do that.

I'm not sure I totally agree with his focus, but I think his point needs to be made and you need to respond to it.

Mr. REMBLESKE. Well, we have been in the commuter aircraft manufacturing business for a long time, having developed aircraft specifically for that purpose back in the late sixties. Several years ago, approximately 5 or 6, we made a detailed study, wanting to get back into the commuter marketplace, because we felt it was a coming segment of industry which was going to grow very rapidly.

At that time we looked at three types of aircraft. We looked at an aircraft which was 19-passengers or less, and a lot of people wonder why 19 because there are several aircraft of that type. Well, that's the breakover point where, if you go larger, you need attendants in the cabin. In other words, if you build a 20-place airplane, you immediately lose revenue due to the fact you have to carry a cabin attendant.

We looked at the 19 passenger or less. We looked at the area from 20 passengers to 35, and then we looked at above 35, up to 60 or 70. We concluded that the marketplace would not justify many participants in that market area of above 19 passengers. We felt that by far the most promising area to enter would be the smaller aircraft and that's why we entered into that aircraft. We still feel that it's going to be most difficult to economically build an aircraft of the larger size under a free enterprise system and make a profit. Larger than 19 passengers. Again, that's a cutoff point and where you get into more complex regulation, the aircraft themselves become more complex, and they will obviously then be much more expensive.

Mr. GLICKMAN. And the other companies do it because they get Government financing and low interest Government loans———

Mr. REMBLESKE. Yes; the people who have embarked in those areas have been largely Government subsidized.

Mr. GLICKMAN. OK. We thank you all for excellent testimony.

This concludes the hearing today. It has been a very useful hearing that we intend to build upon when we begin the authorization process next year. I assume we'll be talking to all of you in reference to what numbers and what specifics go into that bill. So the hearing is adjourned.

[Whereupon, at 1:30 p.m., the subcommittee adjourned, subject to the call of the Chair.]

APPENDIX I

CHANGES TO ORAL TESTIMONY SUBMITTED BY DR. MARK

[1] The C-8A augmentor wing;
[2] . . . a lower risk of failure.
[3] We are supporting the DOD in development of a production vehicle.
[4] . . . The Second World War
[5] Boeing.
[6] . . . wing
[7] TFX
[8] . . . and go to a fixed geometry.
[9] Both are a fallout from military applications.
[10] . . . a direct military application . . .
[11] . . . required for hypersonic flight that people have talked about.
[12] . . . short take off and verticle landing flighter technology.
[13] . . . know they don't work economically.
[14] . . . Certainly in our R&T Base there will be an . . .
[15] . . . I think we knew that back then that it wasn't a research question

[16] I would estimate that there is another $35 million or so, including minor construction a year that goes . . .

[17] . . . 4,500 people, including support, working in aeronautics in NASA and the salaries of those people are never counted in the aeronautics program.

[18] Now, 4,500 people cost us something on the order of $265 or so which when added up you get something close of $600 million in the aeronautics program every year invested by NASA.

[19] Not for that purpose, no. We're looking at some organizational changes, but that's not a driver

APPENDIX II

ADDITIONAL MATERIAL SUBMITTED FOR THE RECORD

YORKTOWN, VA., *November 28, 1983.*

Hon. DAN GLICKMAN,
Chairman, House Committee on Science and Technology,
House of Representatives, Washington, D.C.

DEAR SIR: For some ten years your committee supported a focused aerodynamic technology program on Supersonic Cruise Research within the NASA. I was fortunate to be responsible for the day-to-day management of that program prior to my retirement from NASA in 1978.

I was dismayed to hear of the cancellation of the NASA Supersonic Cruise Research program in 1981 and have been even more dismayed that no focused U.S. aerodynamic program has been initiated to consider truly advanced technology. I even heard that there was some consideration given to striking the entire NASA aerodynamics program out of the Budget.

The degradation of NASA's aerodynamic program has been one of the most serious mistakes this country has made. We have lost sight of the fact that the current Space program is largely a result and outgrowth of earlier aerodynamic research efforts. We have also lost sight of the fact that few, if any, of our advances in aeronautics and/or space resulted from what is commonly referred to as "basic research." Rather, these advances came as a result of "focused" research brought about by a national goal, a national interest, or a national need either now or in the future.

In the past decade I believe that the focus of NASA's aerodynamic research has been motivated more by what can be "sold" to the U.S. Congress (e.g., fuel efficiency, agricultural airplanes, turboprops, etc.) than what should be the focus of our principal advanced aernautical research agency (advanced high-speed research, productivity, performance.)

I urge you and your committee to do what you can to preserve NASA's capability for advanced aeronautical research and to restore a proper focus to this research. The NASA's contributions to this country's aeronautics technology has been made by looking forward into the future, not by looking backwards or to the side.

Respectively,

F. EDWARD MCLEAN.

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